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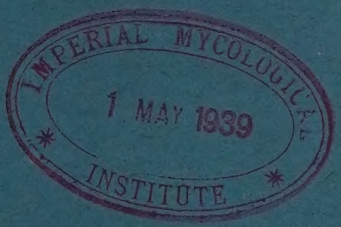

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MATHÉMATIQUES

SUR LES FONCTIONS DE LE ROY, POINCARÉ ET STEKLOFF

Par Kh. SMOLICKIJ

(Présenté par S. N. Bernstein, de l'Académie, le 28. XII. 1938)

1. Dans la Note «Sur les fonctions de Le Roy, Poincaré et V. Stekloff» (1), j'ai démontré que les fonctions de Le Roy, Poincaré et V. Stekloff ne coïncident que pour les surfaces convexes et fermées (sans parties planes), satisfaisant à l'équation

$$\cos(r_{32}n_3)\cos(r_{21}n_2)\cos(r_{13}n_1) - \cos(r_{31}n_3)\cos(r_{23}n_2)\cos(r_{12}n_1) = 0, \quad (A)$$

où (1), (2), (3) désignent les points des surfaces, n_1, n_2, n_3—les normales extérieures, r_{32}, r_{21} etc.—les directions à partir des points du deuxième indice jusqu'aux points du premier. La condition de l'absence des parties planes est une conséquence de la condition que $\cos(r_{21}n_2) \neq 0$ pour chaque couple de points de la surface. Vu cette circonstance, ladite condition doit être remplacée par la condition plus restrictive de l'absence de parties rectilignes.

Il est facile de vérifier, que la sphère et l'ellipsoide satisfont à l'équation (A). Nous allons démontrer dans cette Note qu'à l'équation (A) ne peut satisfaire que l'ellipsoide, en particulier la sphère.

2. Démontrons que chaque section plane de la surface est une ellipse. En considérant une section plane quelconque, choisissons sur elle deux points arbitraires. Un de ces points sera pris pour l'origine des coordonnées, la droite joignant les deux points choisis—pour l'axe Z, et le plan de la section—pour le plan YOZ. Les points choisis ont les coordonnées (o, o, o) et (o, o, c). Soient (α, β, γ) et $(\alpha_1, \beta_1, \gamma_1)$ les cosinus directeurs des normales aux dits points. La surface devant être convexe, on voit que $\gamma \neq 0$, $\gamma_1 \neq 0$. Soit $\varphi(x, y, z) = 0$ l'équation de la surface cherchée.

Considérons trois points sur la surface:

I. (o, o, o) à cosinus directeurs de la normale (α, β, γ)

II. (o, o, c) » » » » » » $(\alpha_1, \beta_1, \gamma_1)$

III. (x, y, z) » » » » » » $\left(\frac{1}{\Delta}\frac{\partial\varphi}{\partial x}, \frac{1}{\Delta}\frac{\partial\varphi}{\partial y}, \frac{1}{\Delta}\frac{\partial\varphi}{\partial z}\right)$

où

$$\Delta = \sqrt{\left(\frac{\partial\varphi}{\partial x}\right)^2 + \left(\frac{\partial\varphi}{\partial y}\right)^2 + \left(\frac{\partial\varphi}{\partial z}\right)^2}.$$

Écrivons l'équation (A) pour ces trois points. Comme

$$\cos(r_{32}n_3) = \qquad \cos(r_{31}n_3) =$$
$$= \frac{1}{\Delta r_{32}}\left[x\frac{\partial\varphi}{\partial x} + y\frac{\partial\varphi}{\partial y} + (z-c)\frac{\partial\varphi}{\partial z}\right] \qquad = \frac{1}{\Delta r_{31}}\left(x\frac{\partial\varphi}{\partial x} + y\frac{\partial\varphi}{\partial y} + z\frac{\partial\varphi}{\partial z}\right)$$
$$\cos(r_{21}n_2) = \gamma_1 \qquad \cos(r_{23}n_2) =$$
$$= -\frac{1}{r_{23}}[\alpha_1 x + \beta_1 y + \gamma_1(z-c)]$$
$$\cos(r_{13}n_1) = -\frac{1}{r_{13}}(\alpha x + \beta y + \gamma z) \qquad \cos(r_{12}n_1) = -\gamma$$

on obtient en substituant dans l'équation (A)

$$x\frac{\partial\varphi}{\partial x}(Kx + Ly + 2z\gamma\gamma_1 - c\gamma\gamma_1) + y\frac{\partial\varphi}{\partial y}(Kx + Ly + 2z\gamma\gamma_1 - c\gamma\gamma_1) +$$
$$+ \frac{\partial\varphi}{\partial z}[z(Kx + Ly + 2z\gamma\gamma_1 - c\gamma\gamma_1) - c\gamma_1(\alpha x + \beta y + \gamma z)] = 0,$$

où

$$K = \gamma\alpha_1 + \gamma_1\alpha, \quad L = \gamma\beta_1 + \gamma_1\beta.$$

Les équations différentielles des lignes caractéristiques sont

$$\frac{dx}{x(Kx + Ly + 2z\gamma\gamma_1 - c\gamma\gamma_1)} = \frac{dy}{y(Kx + Ly + 2z\gamma\gamma_1 - c\gamma\gamma_1)} =$$
$$= \frac{dz}{z(Kx + Ly + 2z\gamma\gamma_1 - c\gamma\gamma_1) - c\gamma_1(\alpha x + \beta y + \gamma z)}.$$

Les intégrales de ce système sont

$$\frac{x}{y} = c_1; \quad \frac{\gamma(\alpha x + \beta y + \gamma z)(c\gamma_1 - \alpha_1 x - \beta_1 y - \gamma_1 z)}{y^2} = c_2$$

et les lignes caractéristiques ont les équations

$$x = c_1 y; \quad \gamma(\alpha x + \beta y + \gamma z)(c\gamma_1 - \alpha_1 x - \beta_1 y - \gamma_1 z) = c_2 y^2.$$

La section choisie $x = 0$ est la ligne caractéristique et elle est donnée par l'équation $\gamma(\beta y + \gamma z)(c\gamma_1 - \beta_1 y - \gamma_1 z) = c_2 y^2$. C'est une courbe du second degré, ou bien l'ensemble de deux droites. Ce dernier cas est exclu, car la surface ne doit pas avoir de parties rectilignes.

Les points (o, o, o) et (o, o, c) sont les points singuliers pour l'équation différentielle [toutes les lignes caractéristiques passent par les points (o, o, o) et (o, o, c)]; il est nécessaire de démontrer, que la section est une courbe du second degré toute entière, mais ne se compose pas d'arcs de deux courbes du second degré distinctes, ayant des tangentes communes aux points (o, o, o) et (o, o, c). En effet, les points (o, o, o) et (o, o, c) sont des points arbitraires sur la section plane, et par conséquent, une partie arbitraire de la section est un arc d'une seule courbe du second degré. Comme la section doit être fermée et convexe, elle est une ellipse.

Nous avons ainsi démontré que chaque section plane est une ellipse. Il est alors facile d'établir que la surface est un ellipsoide, en particulier une sphère.

Il en suit que les fonctions sphériques et les fonctions de Lamé sont les seules fonctions, qui sont simultanément des fonctions de Le Roy, Poincaré et V. Stekloff.

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LITTÉRATURE CITÉE

[1] Kh. Smolickij, C. R. Acad. Sci. URSS, XVI, No 1 (1937).

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MECHANICS

PLANE PROBLEM OF EARTH PRESSURE

By V. SOKOLOVSKY

(Communicated by I. M. Vinogradow, Member of the Academy, 17.XII.1938)

The basic equations of the plane problem of earth pressure are the body stress equations:

$$\frac{\partial \sigma_x}{\partial x}+\frac{\partial \tau_{xy}}{\partial y}+\overline{X}=0, \quad \frac{\partial \tau_{xy}}{\partial x}+\frac{\partial \sigma_y}{\partial y}+\overline{Y}=0 \tag{1}$$

and the condition

$$\sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)^2+\tau_{xy}^2}-\sin\rho\,\frac{\sigma_x+\sigma_y}{2}=K, \tag{2}$$

where ρ and K are respectively the coefficients of friction and cohesion of the medium.

Assuming that

$$\left.\begin{aligned}\sigma_x&=\sigma[1+\sin\rho\sin(2\varphi+\rho)]-\frac{K}{\sin\rho},\\ \sigma_y&=\sigma[1-\sin\rho\sin(2\varphi+\rho)]-\frac{K}{\sin\rho},\quad \tau_{xy}=-\sigma\sin\rho\cos(2\varphi+\rho)\end{aligned}\right\} \tag{3}$$

substituting these expressions into the equations (1) and introducing the denotations

$$\frac{\operatorname{ctg}\rho}{2}\ln\sigma+\varphi=\xi, \quad \frac{\operatorname{ctg}\rho}{2}\ln\sigma-\varphi=\eta, \tag{4}$$

we obtain

$$\frac{\partial\xi}{\partial x}\cos\varphi+\frac{\partial\xi}{\partial y}\sin\varphi+\frac{1}{\sigma}A=0, \quad \frac{\partial\eta}{\partial x}\sin(\varphi+\rho)-\frac{\partial\eta}{\partial y}\cos(\varphi+\rho)+\frac{1}{\sigma}B=0,$$

where

$$A=\frac{1}{2\sin\rho}[\overline{X}\cos(\varphi+\rho)+\overline{Y}\sin(\varphi+\rho)], \quad B=\frac{1}{2\sin\rho}[\overline{X}\sin\varphi-\overline{Y}\cos\varphi].$$

If we assume α and β to be independent variables, with $\alpha(x,y)=\text{const}$ being the first and $\beta(x,y)=\text{const}$ the second family of characteristics coinciding with the lines of slip, we obtain the following system of equations*:

$$\left.\begin{aligned}&\frac{\partial y}{\partial\beta}\cos\varphi-\frac{\partial x}{\partial\beta}\sin\varphi=0, \quad \frac{\partial y}{\partial\alpha}\sin(\varphi+\rho)+\frac{\partial x}{\partial\alpha}\cos(\varphi+\rho)=0,\\ &\frac{\partial\xi}{\partial\beta}+\frac{1}{\sigma\cos\varphi}\frac{\partial x}{\partial\beta}A=0, \quad \frac{\partial\eta}{\partial\alpha}+\frac{1}{\sigma\sin(\varphi+\rho)}\frac{\partial x}{\partial\alpha}B=0.\end{aligned}\right\} \tag{5}$$

* φ is the angle of slope of the line $\alpha=\text{const}$ with respect to the axis x.

If the mass forces are absent ($\overline{X}=\overline{Y}=0$), instead of the equations (5) we shall obtain:

$$\frac{\partial y}{\partial \eta}\cos\varphi-\frac{\partial x}{\partial \eta}\sin\varphi=0,\quad \frac{\partial y}{\partial \xi}\sin(\varphi+\rho)+\frac{\partial x}{\partial \xi}\cos(\varphi+\rho)=0 \tag{6}$$

which, by the substitution

$$x=\frac{1}{\sqrt{\sigma}}[\cos\varphi X-\sin(\varphi+\rho)Y],\quad y=\frac{1}{\sqrt{\sigma}}[\sin\varphi X+\cos(\varphi+\rho)Y]$$

may be reduced to the form

$$\frac{\partial X}{\partial \xi}-\frac{Y}{2\cos\rho}=0,\quad \frac{\partial Y}{\partial \eta}-\frac{X}{2\cos\rho}=0,$$

where $\xi=\text{const}$ is the first and $\eta=\text{const}$ the second family of characteristics.

If the mass forces are present, put

$$u=\sqrt{\sigma}\frac{\partial \varphi}{\partial \alpha}R_\alpha \text{ and } v=\sqrt{\sigma}\frac{\partial \varphi}{\partial \beta}R_\beta,$$

where R_α and R_β are respectively the radii of curvature of the characteristics $\beta=\text{const}$ and $\alpha=\text{const}$, and we obtain:

$$u=\frac{\sqrt{\sigma}}{\sin(\varphi+\rho)}\frac{\partial x}{\partial \alpha},\quad v=-\frac{\sqrt{\sigma}}{\cos\varphi}\frac{\partial x}{\partial \beta} \tag{7}$$

$$\frac{\partial x}{\partial \alpha}=\frac{\sin(\varphi+\rho)}{\sqrt{\sigma}}u,\quad \frac{\partial x}{\partial \beta}=-\frac{\cos\varphi}{\sqrt{\sigma}}v. \tag{7'}$$

Using the formulae (5) and (7'), we obtain the basic system of equations in the following form:

$$\left.\begin{aligned}&\frac{\partial \xi}{\partial \beta}-e^{-\frac{3\operatorname{tg}\rho(\xi+\eta)}{2}}Av=0,\quad \frac{\partial \eta}{\partial \alpha}+e^{-\frac{3\operatorname{tg}\rho(\xi+\eta)}{2}}Bu=0,\\ &\frac{\partial u}{\partial \beta}-\operatorname{tg}\rho\frac{\partial \xi}{\partial \beta}u-\frac{1}{2\cos\rho}\left(\frac{\partial \xi}{\partial \alpha}-\frac{\partial \eta}{\partial \alpha}\right)v=0,\\ &\frac{\partial v}{\partial \alpha}-\operatorname{tg}\rho\frac{\partial \eta}{\partial \alpha}v+\frac{1}{2\cos\rho}\left(\frac{\partial \xi}{\partial \beta}-\frac{\partial \eta}{\partial \beta}\right)u=0.\end{aligned}\right\} \tag{8}$$

Below we shall arrive at the solution of Cauchy, Goursat and the mixed problem for the equations (5); but the solution of these problems is more conveniently obtained for the equations (8).

Having determined $u=u(\alpha,\beta)$, $v=v(\alpha,\beta)$, it is easy to find $x=x(\alpha,\beta)$, $y=y(\alpha,\beta)$ by means of equations (7').

Using the obtained equations, we proceed now to analyse the solution of several basic problems of the theory of earth pressure.

Remembering the formula (3), we easily find the stresses:

$$\sigma_n=\sigma[1+\sin\rho\sin(2\varphi-2\theta+\rho)]-\frac{K}{\sin\rho},\quad \tau_{nt}=-\sigma\sin\rho\cos(2\varphi-2\theta+\rho) \tag{9}$$

where θ is the angle of slope of the normal n with respect to the axis x.

Pressure of Earth on a Supporting Wall

Along the supporting wall, which we assume to be plane,

$$\tau_{nt}=\sigma_n\operatorname{tg}\rho_1, \tag{10}$$

where ρ_1 is the friction coefficient of earth against the wall.

From formulae (9) and (10) we obtain:

$$\sigma = \frac{K \sin \rho_1}{\sin \rho \left[\sin \rho_1 + \sin \rho \cos (2\varphi - 2\theta + \rho - \rho_1)\right]} \tag{11}$$

so that

$$\sigma \geqslant \frac{K \sin \rho_1}{\sin \rho (\sin \rho_1 + \sin \rho)}.$$

Substituting (11) into (4), we obtain a curve; the first branch of this curve will be *:

$$\xi = \xi^*(\varphi),\ \eta = \eta^* \text{ or } \eta = F_1(\xi) \quad \left(\theta - \frac{\rho}{2} + \frac{\rho_1}{2} \leqslant \varphi \leqslant \theta - \frac{\rho}{2} + \frac{\rho_1}{2} + \frac{\gamma}{2} + \frac{\pi}{4}\right); \tag{12'}$$

the second branch of this curve will be:

$$\xi = \xi^*(\varphi),\ \eta = \eta^* \text{ or } \eta = F_2(\xi) \quad \left(\theta - \frac{\rho}{2} + \frac{\rho_1}{2} - \frac{\pi}{4} - \frac{\gamma}{2} \leqslant \varphi \leqslant \theta - \frac{\rho}{2} + \frac{\rho_1}{2}\right). \tag{12''}$$

For crumbling medium ($K = 0$) this curve degenerates into two straight lines:

$$\eta = -2\theta + \rho - \rho_1 - \frac{\pi}{2} - \gamma + \xi, \quad \varphi = \theta - \frac{\rho}{2} + \frac{\rho_1}{2} + \frac{\pi}{4} + \frac{\gamma}{2}, \tag{12'}$$

$$\eta = -2\theta + \rho - \rho_1 + \frac{\pi}{2} + \gamma + \xi, \quad \varphi = \theta - \frac{\rho}{2} + \frac{\rho_1}{2} - \frac{\pi}{4} - \frac{\gamma}{2}. \tag{12''}$$

Let us determine the active pressure of earth on the supporting wall when a normal load $\sigma_x(y)$ is applied along MN (Fig. 1, *a*), and $\tau_{xy} = 0$ **.

According to formulae (3) we obtain

$$\text{either } \varphi = \frac{\pi}{4} - \frac{\rho}{2}, \quad \sigma_x = \sigma(1 + \sin \rho) - \frac{K}{\sin \rho}, \text{ i. e. } \sigma = \frac{\sigma_x + \dfrac{K}{\sin \rho}}{1 + \sin \rho}, \tag{13'}$$

and substituting (13') into (4),

$$\xi = \frac{\operatorname{ctg} \rho}{2} \ln \sigma(y) + \frac{\pi}{4} - \frac{\rho}{2}, \quad \eta = -\frac{\pi}{2} + \rho + \xi, \tag{14'}$$

$$\text{or} \quad \varphi = \frac{3\pi}{4} - \frac{\rho}{2}, \quad \sigma_x = \sigma(1 - \sin \rho) - \frac{K}{\sin \rho}, \text{ i. e. } \sigma = \frac{\sigma_x + \dfrac{K}{\sin \rho}}{1 - \sin \rho}, \tag{13''}$$

and substituting (13'') into (4),

$$\xi = \frac{\operatorname{ctg} \rho}{2} \ln \sigma(y) + \frac{3\pi}{4} - \frac{\rho}{2}, \quad \eta = -\frac{3\pi}{2} + \rho + \xi. \tag{14''}$$

Let us analyse the case $\sigma_x'(y) > 0$ corresponding to a monotonous increase of the load along the y axis (Fig. 1, *a*).

We first consider the problem in the case of absence of mass forces ($\overline{X} = \overline{Y} = 0$). The plane (ξ, η) consists of two superimposed sheets. The straight line $\mu_{01}\mu_{10}$ is the image of (14') on the upper sheet and along it we shall have ***:

$$[x] = 0, \ [y] = y, \ \left[\frac{\partial x}{\partial \xi}\right] = -\frac{1 + \sin \rho}{2 \cos \rho\, \xi'(y)}, \ \left[\frac{\partial x}{\partial \eta}\right] = \frac{1 + \sin \rho}{2 \cos \rho\, \eta'(y)}, \tag{15}$$

where $\xi(y)$ and $\eta(y)$ are given by the formulae (14').

---

* $\gamma = \arcsin \dfrac{\sin \rho_1}{\sin \rho}$, where $0 \leqslant \gamma \leqslant \dfrac{\pi}{2}$.

** It is assumed that $\sigma_x(y)$ has a continuous derivative; the case when $\tau_{xy} \neq 0$ may be also considered.

*** [ ] denote that the function is taken on the line $\mu_{01}\mu_{10}$.

To solve the Cauchy problem for the equations (6), we determine x, y in the triangle $\mu_{01}\mu_{11}\mu_{10}$, and consequently along $\mu_{01}\mu_{11}$.

Let us join both sheets of the plane (ξ, η) along the part of the characteristic $\mu_{01}\mu_{11}$. On the lower sheet let us plot the curve (12″), the intersections of which with the characteristics $\eta = \text{const}$ passing through the points μ_{01} and μ_{10} will give the points μ_{02} and μ_{13}. To the part of the characteristic $\mu_{01}\mu_{02}$ in the plane (x, y) corresponds one point M with co-ordinates (0,0); therefore along $\mu_{01}\mu_{02}$ we assume

$$x = 0, \quad y = 0. \tag{16}$$

To solve the Goursat problem for the equations (6) with reference to the values along $\mu_{01}\mu_{11}$ and $\mu_{01}\mu_{02}$, let us determine x, y on the lower sheet in the rectangle $\mu_{01}\mu_{11}\mu_{12}\mu_{02}$, and consequently along $\mu_{02}\mu_{12}$. Along $\mu_{02}\mu_{13}$ we have

$$x + \operatorname{tg}\theta y = 0. \tag{16'}$$

Solving the mixed problem for the equations (6), we find in the triangle $\mu_{02}\mu_{12}\mu_{13}$

$$x = x(\xi, \eta), \quad y = y(\xi, \eta). \tag{17}$$

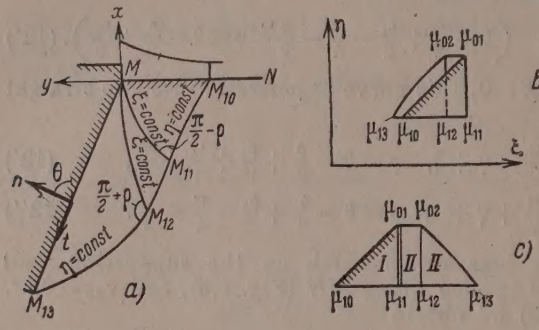

Fig. 1.

The two-sheeted region represented on Fig. 1, *b* may be obtained by means of folding the region represented on Fig. 1, *c* along $\mu_{01}\mu_{11}$. Therefore the construction of the solution in two planes, as it was shown above, may be performed in the corresponding triangles and the rectangle of Fig. 1, *c* *.

Inverting the functions (17), we find:

$$\xi = \xi(x, y), \quad \eta = \eta(x, y). \tag{18}$$

We have proved the following proposition:

Up to the line of discontinuity $\frac{D(\xi, \eta)}{D(x, y)} = \infty$, corresponding to cracks, the functions (18) are univalent.

Substituting the values (18) along MM_{13} $\xi(x, -\operatorname{ctg}\theta x) = \xi^*(x)$, $\eta(x, -\operatorname{ctg}\theta x) = \eta^*(x)$ into (4), we obtain $\sigma = \sigma^*(x)$, $\varphi = \varphi^*(x)$, and then by (9) we find:

$$\sigma_n = \sigma_n^*(x), \quad \tau_{nt} = \tau_{nt}^*(x). \tag{19}$$

Let us extend the above solution to the case of presence of mass forces (the weight of the earth is taken into account). In this case the characteristics will be $\alpha = \text{const}$ and $\beta = \text{const}$.

We now consider the plane (α, β) as consisting of two superimposed sheets. In the choice of α and β we have some freedom which we shall later make use of.

On the upper sheet let us choose α and β so that along MM_{10} they should coincide with (14′):

---

* The corresponding points μ_{ik} are denoted on Fig. 1, *b* and 1, *c* identically.

$$\alpha = \alpha(y) = \xi(y), \quad \beta = -\frac{\pi}{2} + \rho + \alpha. \tag{20}$$

The image of (20) on the upper sheet (α, β) coincides with the image of (14′) on (ξ, η) (Fig. 1, *b*), along which we shall have:

$$\left.\begin{aligned} [x] = 0,\ [y] = y,\ [\xi] = \xi(y),\ (\eta) = -\frac{\pi}{2} + \rho + \xi(y), \\ \left[\frac{\partial x}{\partial \alpha}\right] = -\frac{1+\sin\rho}{2\cos\rho\xi'(y)},\ \left[\frac{\partial x}{\partial \beta}\right] = \frac{1+\sin\rho}{2\cos\rho\eta'(y)}, \\ \left[\frac{\partial \xi}{\partial \alpha}\right] = 1 + \frac{2\sin\left(\frac{\pi}{4}+\frac{\rho}{2}\right)}{\cos\rho\,\mathrm{ctg}\,\rho\sigma'(y)}A,\ \left[\frac{\partial \eta}{\partial \beta}\right] = 1 - \frac{2\sin\left(\frac{\pi}{4}+\frac{\rho}{2}\right)}{\cos\rho\,\mathrm{ctg}\,\rho\sigma'(y)}B. \end{aligned}\right\} \tag{21}$$

Joining both sheets along the part $\mu_{01}\mu_{11}$ and using the remaining freedom in the choice of α on the lower sheet, we may obtain that the equation of the curve $\mu_{01}\mu_{13}$ coincides with (12″), i. e. that $\beta = F_2(\alpha)$.

The intersections of this curve with the characteristics $\beta = \text{const}$ passing through the points μ_{01} and μ_{10} will give the points μ_{02} and μ_{13}.

Along the part $\mu_{01}\mu_{02}$ of the characteristic $\beta = \eta(0)$ let us assume that $\alpha = \xi$. Thus,

along $\mu_{01}\mu_{02}$: $$x = 0,\ y = 0,\ \xi = \alpha, \tag{22}$$

along $\mu_{02}\mu_{13}$: $$x + \mathrm{tg}\,\theta y = 0,\ \xi = \xi(y),\ \eta = F_2(\xi). \tag{22′}$$

All the points μ_{ik} in the plane (α, β) coincide with the corresponding points in the plane (ξ, η).

Therefore, solving the Cauchy, Goursat and the mixed problem for the equations (5), in the same regions as in the case of absence of the mass forces we obtain in the triangle $\mu_{02}\mu_{12}\mu_{13}$:

$$x = x(\alpha, \beta),\ y = y(\alpha, \beta),\ \xi = \xi(\alpha, \beta),\ \eta = \eta(\alpha, \beta). \tag{23}$$

Inverting the first two functions (23), we obtain

$$\alpha = \alpha(x, y),\ \beta = \beta(x, y). \tag{24}$$

We have proved the following proposition:

Up to the line of discontinuity $\frac{D(\alpha, \beta)}{D(x, y)} = \infty$, corresponding to cracks, the functions (24) are univalent. All other reasonings remain the same.

Quite in the same way the problem is solved in the cases

$$\sigma_x'(y) < 0 \text{ and } \sigma_x = \text{const}.$$

If the load consists of several portions in each of which it varies monotonously, the planes (ξ, η) and (α, β) will be manysheeted and all other reasonings proceed as above.

For the determination of the passive earth pressure the formulae (12″) and (14′) should be replaced by (12′) ane (14″) respectively.

The method developed in this paper may be applied to the solution of several other problems of the theory of earth pressure.

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THEORY OF ELASTICITY

ON SECONDARY EFFECTS ARISING AT THE TORSION OF AN ELLIPTICAL CYLINDER

By D. PANOV

(Communicated by I. M. Vinogradow, Member of the Academy, 11. XII. 1938)

1. The problem of the secondary effects (i. e. effects, which become revealed in the solution carried out to terms of the order τ^2 inclusively, where τ denotes the torque) arising at the torsion has been so far solved only for the circular rod ([1], [2]), whereby the axial symmetry was essentially used. In the present note we give an exact solution of the problem of secondary effects arising at the torsion of an elliptical cylinder by the use of a method which can be extended to the case of a prismatical rod with a cross-section, whose torsion function is a polynomial.

2. We solve the problem in the co-ordinates x, y, z of the final state using the following relations between the displacements and the strain and stress components:

$$\left.\begin{aligned} \varepsilon_{xx} &= \frac{\partial u}{\partial x} - \frac{1}{2}\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial x}\right)^2 + \left(\frac{\partial w}{\partial x}\right)^2\right], \\ \varepsilon_{xy} &= \frac{1}{2}\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right) - \frac{1}{2}\left[\frac{\partial u}{\partial x}\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\frac{\partial v}{\partial y} + \frac{\partial w}{\partial x}\frac{\partial w}{\partial y}\right], \end{aligned}\right\} \tag{1}$$

$$\left.\begin{aligned} X_x &= (\lambda+2\mu)\,\varepsilon_{xx} + \lambda(\varepsilon_{yy}+\varepsilon_{zz}) + \frac{3}{2}(\lambda+2\mu)\,\varepsilon_{xx}^2 + \frac{\lambda}{2}(\varepsilon_{yy}^2+\varepsilon_{zz}^2) - \\ &\quad - (\lambda+2\mu)(\varepsilon_{xx}\varepsilon_{yy}+\varepsilon_{xx}\varepsilon_{zz}) - 2\lambda\varepsilon_{yy}\varepsilon_{zz} + \\ &\quad + (3\lambda+5\mu)(\varepsilon_{xy}^2+\varepsilon_{xz}^2) + 3\lambda\varepsilon_{yz}^2; \\ X_y &= 2\mu\varepsilon_{xy} + (\lambda+3\mu)(\varepsilon_{xx}\varepsilon_{xy}+\varepsilon_{yy}\varepsilon_{xy}) + \\ &\quad + (\lambda-2\mu)\,\varepsilon_{xy}\varepsilon_{zz} + 5\mu\varepsilon_{xz}\varepsilon_{yz}. \end{aligned}\right\} \tag{2}$$

The formulae (2) are Murnaghan's formulae ([3]), in which the constants are determined according to Riz-Zvolinsky's hypothesis ([4]).

Beside the formulae (1) and (2) we have the equation of equilibrium

$$\frac{\partial X_x}{\partial x} + \frac{\partial X_y}{\partial y} + \frac{\partial X_z}{\partial z} = 0 \tag{3}$$

and the boundary conditions

$$X_x\cos\alpha + X_y\cos\beta + X_z\cos\gamma = 0 \tag{4}$$

of the deformed surface.

We consider a cylinder, whose cross-section is an ellipse with semi-axes a and b.

Putting

$$u = -\tau yz + \tau^2 U,\quad v = \tau xz + \tau^2 V,\quad w = \tau Cxy + \tau^2 W, \tag{5}$$

where

$$C = -\frac{a^2 - b^2}{a^2 + b^2},$$

we obtain from the formulae (1) — (4) the following equations for U, V and W:

$$\left.\begin{aligned}
(\lambda+\mu)\frac{\partial\Theta}{\partial x} + \mu\Delta U &= -\frac{1}{4}\left[2\lambda\left(C^2+6C+1\right)+\mu\left(C^2-9\right)\right]x,\\
(\lambda+\mu)\frac{\partial\Theta}{\partial y} + \mu\Delta V &= -\frac{1}{4}\left[2\lambda\left(C^2-6C+1\right)+\mu\left(C^2-9\right)\right]y,\\
(\lambda+\mu)\frac{\partial\Theta}{\partial z} + \mu\Delta W &= 2\left(\lambda+\mu\right)z,
\end{aligned}\right\} \tag{6}$$

and the boundary conditions

$$\left.\begin{aligned}
&\lambda\Theta\cos\alpha_0 + \mu\left(\frac{\partial U}{\partial\nu_0} + \frac{\partial U}{\partial x}\cos\alpha_0 + \frac{\partial V}{\partial x}\cos\beta_0\right) =\\
&= \left[\left(\lambda+\mu\right)z^2 - \frac{1}{4}\lambda\left(C^2+6C+1\right)x^2 - \frac{1}{4}\left(\lambda+\mu\right)\left(C^2-6C+1\right)y^2\right]\times\\
&\quad\times\cos\alpha_0 - \frac{1}{4}\mu\left(C^2-4C-1\right)xy\cos\beta_0;\\
&\lambda\Theta\cos\beta_0 + \mu\left(\frac{\partial V}{\partial\nu_0} + \frac{\partial U}{\partial y}\cos\alpha_0 + \frac{\partial V}{\partial y}\cos\beta_0\right) =\\
&= -\frac{1}{4}\mu\left(C^2+4C-1\right)xy\cos\alpha_0 + \left[\left(\lambda+\mu\right)z^2 -\right.\\
&\left. -\frac{1}{4}\lambda\left(C^2-6C+1\right)y^2 - \frac{1}{4}\left(\lambda+\mu\right)\left(C^2+6C+1\right)x^2\right]\cos\beta_0;\\
&\mu\left(\frac{\partial W}{\partial\nu_0} + \frac{\partial U}{\partial z}\cos\alpha_0 + \frac{\partial V}{\partial z}\cos\beta_0\right) =\\
&= -\mu\left(2C-1\right)xz\cos\alpha_0 + \mu\left(2C+1\right)yz\cos\beta_0,
\end{aligned}\right\} \tag{7}$$

which must be satisfied on the surface

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1. \tag{8}$$

In the formulae (7) $\cos\alpha_0$, $\cos\beta_0$ and $\frac{\partial}{\partial\nu_0}$ are connected with the normal to the surface (8).

3. It can be shown that the solution of equations (6) satisfying the boundary conditions (7) has the following form:

$$\left.\begin{aligned}
U &= \frac{1}{2}xz^2 + A_1x^3 + A_2xy^2 + \frac{\lambda+2\mu}{4\mu\left(\lambda+\mu\right)}\left[2A_3x + 12A_4xy^2 -\right.\\
&\left. - \frac{12\left(A_4+A_5\right)}{b^2\left(\frac{3}{a^4}+\frac{3}{b^4}+\frac{2}{a^2b^2}\right)}\left(\frac{x^3}{3a^2}+\frac{3xy^2}{b^2}-x\right)\right] - \frac{\lambda}{4\mu\left(\lambda+\mu\right)}\left[2A_6x +\right.\\
&\left. + 4A_5x^3 - \frac{12\left(A_4+A_5\right)}{a^2\left(\frac{3}{a^4}+\frac{3}{b^4}+\frac{2}{a^2b^2}\right)}\left(\frac{x^3}{a^2}+\frac{xy^2}{b^2}-x\right)\right];\\
V &= \frac{1}{2}yz^2 + A_7x^2y + A_8y^3 + \frac{\lambda+2\mu}{4\mu\left(\lambda+\mu\right)}\left[2A_6y + 12A_5x^2y -\right.\\
&\left. - \frac{12\left(A_4+A_5\right)}{a^2\left(\frac{3}{a^4}+\frac{3}{b^4}+\frac{2}{a^2b^2}\right)}\left(\frac{3x^2y}{a^2}+\frac{y^3}{3b^2}-y\right)\right] - \frac{\lambda}{4\mu\left(\lambda+\mu\right)}\left[2A_3y +\right.\\
&\left. + 4A_4y^3 - \frac{12\left(A_4+A_5\right)}{b^2\left(\frac{3}{a^4}+\frac{3}{b^4}+\frac{2}{a^2b^2}\right)}\left(\frac{x^2y}{a^2}+\frac{y^3}{b^2}-y\right)\right];\\
W &= C\left(y^2-x^2\right)z + hz.
\end{aligned}\right\} \tag{9}$$

In these formulae

$$\left.\begin{aligned}
A_1 &= \frac{1}{6(3\lambda+2\mu)}\left[\lambda C^2-(\lambda+2\mu)C+\lambda-\frac{\lambda}{\mu}\delta-\frac{\lambda}{2\mu}\varkappa\right];\\
A_2 &= \frac{1}{8(3\lambda+2\mu)}\left[(\lambda-2\mu)C^2-\frac{1}{\lambda}(14\lambda^2+52\lambda\mu+32\mu^2)C-\right.\\
&\qquad\left.-(11\lambda+10\mu)+\frac{8(\lambda+\mu)}{\mu}\delta-\frac{2\lambda}{\mu}\varkappa\right];\\
A_3 &= -\frac{1}{2}\mu C a^2;\\
A_4 &= \frac{1}{12}\left[\frac{4(\lambda+\mu)}{\lambda}\mu C-\mu\frac{a^2}{b^2}+\mu+2\mu\frac{a^2}{b^2}C-\delta\right];\\
A_5 &= \frac{1}{12}\left[\frac{4(\lambda+\mu)}{\lambda}\mu C+\mu\frac{b^2}{a^2}-\mu+2\mu\frac{b^2}{a^2}C+\delta\right];\\
A_6 &= \frac{1}{2}\mu C b^2;\\
A_7 &= \frac{1}{8(3\lambda+2\mu)}\left[(\lambda-2\mu)C^2+\frac{1}{\lambda}(14\lambda^2+52\lambda\mu+32\mu^2)C-\right.\\
&\qquad\left.-(11\lambda+10\mu)+\frac{8(\lambda+\mu)}{\mu}\delta-\frac{2\lambda}{\mu}\varkappa\right];\\
A_8 &= \frac{1}{6(3\lambda+2\mu)}\left[\lambda C^2+(\lambda+2\mu)C+\lambda-\frac{\lambda}{\mu}\delta-\frac{\lambda}{2\mu}\varkappa\right];\\
\delta &= \frac{1}{4\lambda}\left[4(\lambda+\mu)\varkappa-(11\lambda\mu+10\mu^2)C^2-(22\lambda\mu+20\mu^2)C+\right.\\
&\qquad\left.+(\lambda\mu-2\mu^2)\right];\\
\varkappa &= \frac{1}{4(\lambda+2\mu)}\left[(13\lambda\mu+20\mu^2)C^2+(11\lambda\mu+4\mu^2)\right].
\end{aligned}\right\}\qquad(10)$$

The constant h in the expression for W is to be determined from the condition

$$\int\int Z_z\,dxdy=0.$$

Passing to the co-ordinates ξ, η, ζ of the initial state

$$\xi=x-u,\quad \eta=y-\varphi,\quad \zeta=z-w,$$

and taking into account the formulae (5), we obtain:

$$\left.\begin{aligned}
u &= -\tau\eta\zeta-\frac{1}{2}\tau^2\xi\zeta^2+\tau^2A\xi^3+\tau^2B\xi\eta^2;\\
\varphi &= \tau\xi\zeta-\frac{1}{2}\tau^2\eta\zeta^2+\tau^2D\xi^2\eta+\tau^2E\eta^3;\\
w &= \tau C\xi\eta+\tau^2h\zeta.
\end{aligned}\right\}\qquad(11)$$

In these formulae A, B, D, E are certain constants depending on λ, μ, a and b.

The formulae (11) show that if in the problem of the torsion of an elliptical cylinder we take into account terms of the order τ^2, the radii of the cross-sections change their length and, generally speaking, become curved; the length of the rod decreases; an additional distortion of the originally plane cross-section does not arise. The stiffness remains also unchanged.

4. Putting $a=b$ (or $C=0$) we find the solution of the problem of the torsion of a circular cylinder taking into account terms of the order τ^2 given by Riz [2]. In this case the curving of the radii disappears.

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THEORY OF ELASTICITY

ON SOME CASES OF EXACT SOLUTION OF THE TORSION PROBLEM FOR UNSYMMETRICAL DOMAINS

By B. SOLONOUTZ

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1. Till now very few cases of exact solution of the torsion problem are known for domains possessing no axes of symmetry.

For many practical problems, however, such solutions represent certain interest. So, e. g., in the problem of the torsion of an air-screw blade

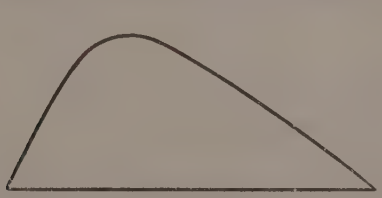

Fig. 1.

Fig. 2.

it is desirable to obtain an exact solution for a contour approximating the unsymmetrical flat-convex screw profile.

2. In order to find such solution we use the inverse method of St.-Venant, assuming that the contour of the domain is an algebraical curve of the sixth order falling into two curves of the third order.

Considering the solutions of the equation

$$\frac{\partial^2\varphi}{\partial x^2}+\frac{\partial^2\varphi}{\partial y^2}=\text{const}, \tag{1}$$

which may be represented in the form of a product of two polynomials of the third degree in x and y, we find that the equation (1) may be solved exactly for the domain bounded by the following curves:

$$(\alpha^2-1)\,x^3+\alpha\,(\alpha^2-5)\,x^2y+(1-5\alpha^2)\,xy^2+\alpha\,(1-\alpha^2)\,y^3+$$
$$+\left[\frac{4\alpha\beta\,(1+\alpha^2)}{3\alpha^2-1}+\frac{(\alpha^2-3)\,(\alpha^2-1)\,\gamma}{1-3\alpha^2}\right]x^2+\frac{2\beta\,(1+\alpha^2)\,(1+3\alpha^2)+8\alpha\gamma\,(\alpha^2-1)}{3\alpha^2-1}\,xy+$$
$$+\gamma y^2+ax+by+c=0, \tag{2}$$
$$y=\alpha x+\beta. \tag{3}$$

By β, γ, a, b, c we denote constants which may be chosen arbitrarily. The constant α must satisfy the condition $\alpha^2\neq 1$.

If $a = \pm 1$, the equation (3) remains unchanged, but the equation (2) must be replaced by

$$x^2y + \alpha xy^2 + (\delta - \beta)x^2 - 2\alpha(\beta - 2\delta)xy + \delta y^2 + ax + by + c = 0. \qquad (2a)$$

Herein δ is a new arbitrary constant.

Assigning to the constants involved in (2) and (3) or (2a) and (3) adequately chosen values, we obtain different domains similar to those given in Figs. 1 and 2.

Fig. 1 represents the case

$$\alpha = -1; \quad \beta = -3; \quad \delta = 0; \quad a = b = 0; \quad c = 1. \qquad \text{(Equation 2a)}$$

Fig. 2 represents the case

$$\alpha = \beta = -1; \quad \delta = -2; \quad a = b = c = 0. \qquad \text{(Equation 2a)}$$

For a different choice of parameters we may also obtain more flat profiles of the type given in Fig. 1; these profiles approximate very closely the flat-convex screw profiles.

For all these cases the stress function is a polynomial.

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PHYSIQUE

LES FOURCHETTES PLATES DES RAYONS COSMIQUES

Par A. JDANOFF

(Présenté par S. I. Wawilow, de l'Académie, le 26. XII. 1938)

Dans un article(1) récemment publié ont été communiqués les résultats préliminaires des expériments concernant les observations de la désintégration des nucleus par des rayons cosmiques à l'aide des plaques photographiques à couches épaisses exposées à des hauteurs (atteignant 9000 m). Il était noté que dans ces plaques des fourchettes originales, «à queue», ont été observées en même temps que des fourchettes dont la distribution des componentes est irrégulière (conformément à la théorie de l'évaporation nucléaire de Bohr) et des fourchettes en «averse» (consistant de protons et de mésotrons).

Dans ces fourchettes «à queue» les faisceaux des componentes plus courtes sont dirigés ordinairement d'un côté, et la cinquième componente, considérablement plus longue, du côté opposé. A l'examen ultérieur des plaques sous microscope on a observé plusieurs cas de fourchettes «à queue», où toutes les componentes se trouvent précisément dans le même plan, et n'en déclinent que de quelques degrés. Deux fourchettes de ce type ont été décrites dans mon rapport à la 2-me Conférence Nucléaire le 1 octobre 1938*.

Les mesures plus précises, effectuées ultérieurement, ont montré que pour une de ces fourchettes (voir le photo) la somme des angles formés par les componentes est 360.5°, quand aux angles même, leur valeur est de 124°, 22.5°, 13.5°, 40° et 160.5° (dans le sens du mouvement de l'aiguille de cadran) et les longueurs des tracks (reduits à l'air) sont 16, 2.8, 3.4, 5.4 et 5.7 cm (le premier track aboutit au verre de la plaque et d'après la disposition de grains on peut présumer que la longueur réelle est plus grande d'à peu près un cm).

Ce qui concerne la classification des tracks, on peut dire que déjà à l'examen préliminaire il paraissait incontestable que le premier track doit être attribué au proton, et le deuxième et le troisième aux particules à l'ionisation moins intense (mésotrons). La classification du quatrième track fut difficile**.

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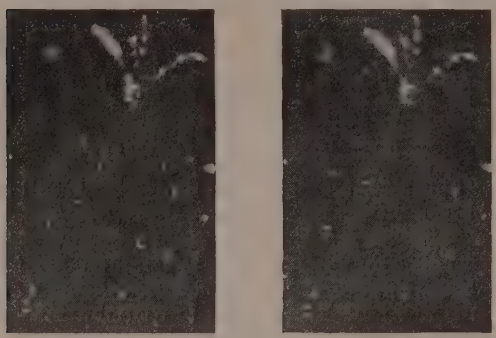
* J'y ai montré que d'après les mesures préliminaires les sommes des angles dans ces fourchettes sont 362 et 358°.

** Un contenu élevé de grains étrangers dans l'emulsion a été observé (ceci peut être expliqué par ce que la confection des plaques et les expériments ont eu lieu pendant un temps chaud). La cause en est que pendant les expériments préliminaires avec un microscope à grossissement relativement petit la quantité des grains calculée paraissait pour certains tracks plus grande que la quantité réelle, ce que amenait un alourdissement apparent des particules.

Un examen plus minutieux des tracks avec un microscope à grossissement plus fort a montré que le dernier track appartient au proton et qu'il serait correct d'attribuer le quatrième au mésotron. Vu que la fourchette donnée se trouve toute entière dans le même plan, il est facile de calculer les moments de particules. En admettant que la direction positive de l'axe X est la direction du mouvement de la particule dans le premier track et la direction qui est perpendiculaire (du côté du 5-ème track) est la direction positive de l'axe Y, on aboutit aux résultats, présentés dans la table.

La moitié supérieure de la table concerne les calculs effectués en admettant que la masse du mésotron $\mu=250\ m_e$(m_e—la masse de l'électron), et pour la moitié inférieure les calculs etaient faits dans la supposition que $\mu=200\ m_e$.



× 320.

La détermination des moments des mésotrons a été effectuée d'après la formule $p=\mu v=\frac{e}{c}H\rho$, où la valeur $H\rho$ pour la masse correspondante μ et la valeur du parcours a été déterminéea à l'aide des nomogrammes de Corson et Brode(2). Quand aux moments des protons, ils ont été calculés d'après la formule $P_H=\sqrt{2Em_H}$, où m_H est la masse du proton et E—son énergie déterminée de la longueur du parcours d'après les courbes de Bethe (3).

	Le numéro du track et sa classification	La valeur du moment (u. a.)	La projection du moment sur l'axe X	La somme des projections sur l'axe X	La projection du moment sur l'axe Y	La somme des projections sur l'axe Y
$\mu=250\ m_e$	1 (H^+)	$41.5\cdot10^{-16}$	$+41.5\cdot10^{-16}$	$+41.5\cdot10^{-16}$	0	0
	2 (M)	$6.1\cdot10^{-16}$	$-3.4\cdot10^{-16}$		$-5.1\cdot10^{-16}$	
	3 (M)	$6.7\cdot10^{-16}$	$-5.5\cdot10^{-16}$	$-44.4\cdot10^{-16}$	$-3.7\cdot10^{-16}$	$-11.3\cdot10^{-16}$
	4 (M)	$7.3\cdot10^{-16}$	$-6.8\cdot10^{-16}$		$-2.5\cdot10^{-16}$	
	5 (H^+)	$30.4\cdot10^{-16}$	$-28.7\cdot10^{-16}$		$+10.2\cdot10^{-16}$	$+10.2\cdot10^{-16}$
$\mu=200\ m_e$	1 (H^+)	$41.5\cdot10^{-16}$	$41.5\cdot10^{-16}$	$+41.5\cdot10^{-16}$	0	0
	2 (M)	$5.3\cdot10^{-16}$	$-2.9\cdot10^{-16}$		$-4.4\cdot10^{-16}$	
	3 (M)	$5.6\cdot10^{-16}$	$-4.6\cdot10^{-16}$	$-42.0\cdot10^{-16}$	$-3.1\cdot10^{-16}$	$-9.7\cdot10^{-16}$
	4 (M)	$6.2\cdot10^{-16}$	$-5.8\cdot10^{-16}$		$-2.2\cdot10^{-16}$	
	5 (H^+)	$30.4\cdot10^{-16}$	$-28.7\cdot10^{-16}$		$+10.2\cdot10^{-16}$	$+10.2\cdot10^{-16}$

La valeur de $41.5\cdot10^{-16}$ u. a. pour le moment du proton dans le premier track a été obtenue en partant de sa longueur mesurée de 16 cm; si l'on prend la longueur possible de son parcours égale à 17 cm, on obtient pour le moment la valeur de $42.0\cdot10^{-16}$ u. a.

En comparant les chiffres soulignés de la table on peut voir que dans ce cas la loi de la conservation de la quantité du mouvement est observée. Ça veut dire aussi que dans le cas du processus représenté par une telle fourchette toutes les particules sont éjectées simultanément.

Ce qui concerne les processus représentés sous la forme des «averses», on peut dire, que d'après les matériaux disponibles (sur les plaques examinées jusqu'à présent le nombre des «averses» enregistrées atteint 50) leur composentes sont les protons et les mésotrons, le nombre de ces derniers en plusieurs cas étant pair.

Les exemples des «averses» et des fourchettes plates (le nombre enregistré de ces fourchettes est jusqu'à présent 4; dans toutes ces fourchettes la ligne perpendiculaire à leur plan forme avec la ligne verticale un angle d'à peu près 15 degrés) nous montrent que dans le cas de l'action réciproque de la radiation cosmique et de la matière, en outre des désintégrations nucléaires correspondant à la conception de Bohr, d'autres processus qui sortent des bornes de cette conception peuvent aussi avoir lieu.

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GEOPHYSICS

ON THE DETERMINATION OF ERRORS OF A GRAVIMETRICAL CONNEXION BETWEEN TWO STATIONS

By J. BOULANGER

(Communicated by S. I. Wawilow, Member of the Academy, 26. XII. 1938)

1. A classical solution of the problem of determining the precision of a gravimetrical connexion between two stations by relative pendulum observations was given by Borrass in 1902.

According to the methods of observation used at his time, Borrass has given formulae by which it was possible to calculate the chief errors of observations and then, by summing them up, to calculate the average value of the mean square error of a station for a given expedition.

In most cases, however, the values of the different errors are of no particular interest, and it is sufficient to know only their sum, i. e. the mean square error of the station. Thereby it is not the average error of the expedition that it is important to know, but the error of every individual station, which cannot be calculated according to Borrass' formulae.

Besides, Borrass' formulae are complicated and therefore inconvenient for the use on a large scale.

Hence it is necessary to find such a method of calculation of the errors, by the use of which it will be possible with sufficient accuracy and economy of labour to obtain directly the mean square error of the determination of gravity acceleration for every separate station of the expedition.

The present paper contains an analysis of such a method.

2. The difference of gravity between two stations is calculated according to the known formula:

$$\Delta g = -2\frac{g_0}{S_0}\Delta S, \qquad (1)$$

where g_0 is the approximate value of gravity, S_0 — the approximate period of the pendulum oscillations at the reference station, and ΔS — the difference of the period between the field and the reference stations. The error of the connexion between two stations will be

$$M^2_{\Delta g} = M^2_{\Delta S}\left(2\frac{g_0}{S_0}\right)^2, \qquad (2)$$

where

$$M^2_{\Delta S} = M^2_S + M^2_{S_0}. \qquad (3)$$

It is understood that M_S and M_{S_0} are mean square errors of the determination of the mean period at the field and the reference stations respectively. These errors can be calculated from three groups of discrepancies in the determination of the period:

1) the discrepancies between intervals in the determination of the period of one pendulum;

2) the discrepancies between the differences «field station minus reference one» calculated for each pendulum;

3) the discrepancies between the initial and the final observations at the reference point.

These discrepancies arise from many sources of errors in the measurement of the period of oscillations of the pendulum and the calculation of its corrections. All these errors can be divided into 4 groups:

1) accidental errors, changing from observation to observation, from period to period, from pendulum to pendulum;

2) semi-systematic errors, influencing equally the periods of all pendulums simultaneously observed, but changing from series to series, from interval to interval;

3) systematic errors, which are constant for a given pendulum at the station, but different for different pendulums;

4) systematic errors, influencing equally the periods of all pendulums and remaining constant for all periods observed at the station.

The last group of errors cannot be determined from the discrepancies between the periods of the pendulums of one instrument. Therefore we will not deal with them any more. Considering the above said, the error of determination of the average period for the given station can be written in the form

$$M_S^2 = \sum I + \sum II + \sum III \tag{4}$$

and for the reference station in the form

$$M_{S_0}^2 = \sum I_0 + \sum II_0, \tag{4a}$$

where $\sum$ is the sum of squares of all mean square errors of the group.

The mean square error of the average period for a given station can be calculated by the oscillations of periods of the separate pendulums from interval to interval according to the formula

$$m = \pm \frac{1}{k} \sqrt{\sum_1^k \left[\frac{\sum_1^n \delta\delta}{n(n-1)} \right]}, \tag{5}$$

where the δ are the corresponding deviations from the average, n, the number of intervals at the point, k, the number of pendulums observed simultaneously.

On the other hand,

$$\left.\begin{aligned} M_S^2 &= m^2 + \sum III, \\ M_{S_0}^2 &= m_0^2. \end{aligned}\right\} \tag{6}$$

Let us calculate the mean square error of the variation of the period by the oscillations of differences «field station minus reference one» for each pendulum. This error will be

$$\mu = \pm \sqrt{\frac{\sum_1^k ss}{k(k-1)}}, \tag{7}$$

where ε is the deviation from the average. But

$$\mu^2 = \sum I + \sum I_0 + \sum III, \tag{8}$$

and therefore we find from equations (3), (4), (6) and (8) that

$$M^2_{\Delta S} = m^2 + m_0^2 + \mu^2 - \sum I - \sum I_0. \tag{9}$$

Pendulum observations, even of an inferior quality, show that the sums $\sum I$ and $\sum I_0$ in comparison with μ^2 and m^2 may be, as a rule, neglected, if the $M_{\Delta S}$ are to be calculated with accuracy about $6-7\%$.

Only for pendulums abruptly changing their periods from interval to interval (with variations of the order $80-100\cdot 10^{-7}$ sec.) it is necessary to take into consideration the errors m_η and m_{η_0} — the errors of the variation of the period of the pendulum from interval to interval making a part of the expressions $\sum I$ and $\sum I_0$.

It may be shown that with the same accuracy

$$m^2_{\eta_0} = \frac{k^2}{k-1} n_0 \lambda_0^2; \quad m^2_{\eta} = \frac{k^2}{k-1} n \lambda^2, \tag{10}$$

where λ is the mean square error of the differences of the type

$$S_k - \frac{1}{k} \sum_1^k S_k \tag{11}$$

calculated for each pendulum separately and then taken in the mean for all pendulums.

Thus, the expression (9) can be written as follows:

$$M^2_{\Delta S} = m^2 + m_0^2 + \mu^2 - \frac{k}{k-1}\lambda^2 - \frac{k}{k-1}\lambda_0^2. \tag{12}$$

In the expression (12) m_0 is the mean square error of the period of the mean pendulum at the reference station. The calculation of the error m_0 by the formula (5) can be applied only in the case when we have to do with accidental errors.

Therefore, if the length of the pendulums has undergone some systematic changes during the expedition, the periods must be adjusted previously to the calculation of m_0. This diminishes the real value of m_0 and this diminuation can be approximately calculated by the formula

$$f_0 = \pm \sqrt{\frac{\sum_1^l \varphi\varphi}{l(l-1)}}, \tag{13}$$

where l is the number of settings at the reference station used in the calculation of Δg, φ — the deviation from the average of the type $S - \frac{1}{l}\sum_1^l S$, and S — the average period of the mean pendulum for a setting.

Thus, the final expression for the error of the connexion between two stations may be written as follows:

$$M_{\Delta S} = \pm \sqrt{m_0^2 + f_0^2 - \frac{k}{k-1}\lambda_0^2 + \mu^2 + m^2 - \frac{k}{k-1}\lambda^2}, \tag{14}$$

which solves the problem in question.

In order to verify the correctness of the deduced formula we have calculated the errors in determination of gravity acceleration by using

the data of an expedition of the Seismological Institute of the Academy of Sciences. We made use of our method, Borrass' method and of the differences of gravity as determined with two instruments, applied simultaneously under the same conditions (the 1st instrument is a four-pendulum instrument of the Stückrath type, «Askania Werke» No 79533, and the 2nd is a three-pendulum instrument of the Cambridge Co, No 136608).

The results are given in Tables 1 and 2.

Table 1

Station	m^2	μ^2	$\frac{k}{k-1}\lambda^2$	f_0^2	$\frac{k}{k-1}\lambda_0^2$	m_0^2	$M^2_{\Delta S}$	$M^2_{\Delta S}$ mgal
1. Telav	+57	+67	−58				+77	±3.4
2. Pshaveli	3	6	0				20	1.7
3. Djakola	0	2	0				13	1.4
4. Achmety	14	66	1				90	3.7
5. Artani	2	60	1				72	3.3
6. Sakaraoulo	1	12	0				24	1.9
7. Gori	16	16	4				39	2.4
8. Medjvris-Chevi	11	20	2				40	2.4
9. Kvelant-Oubani	0	11	0	+ 9	− 3	+ 5	22	1.8
10. Tsitelli-Kolaki	2	108	2				119	4.2
11. Odzisi	9	45	2				63	3.1
12. Monasteri	8	37	1				55	2.9
13. Ordjonikidze	12	56	8				71	3.3
14. Lars	2	6	1				18	1.6
15. Kasbek	13	160	2				182	5.2
16. Goudaour	85	357	98				355	7.3
17. Passanaour	4	38	3				50	2.7
18. Doushet	5	26	0				42	2.5
							$(M_{\Delta S})_{mean} = \pm 3.1$ mgal	
By Borrass' method							$(M_{\Delta S})_{mean} = \pm 3.3$ mgal	

Table 2

Station	Instrument No 1 g_I	Instrument No 2 g_{II}	$g_{II} - g_I$	By new formulae
1. Lars	980.097	980.097	0	± 1.6
2. Kasbek	979.984	979.992	+ 8	5.2
3. Goudaour	979.863	979.854	− 9	7.7
4. Passanaour	980.066	980.069	+ 3	2.7
5. Doushet	980.060	980.059	− 1	2.5
The error of the determination Δg with one instrument:			±3.9 mgal	±3.9 mgal

The full agreement of the results obtained by three different ways makes us assume that the method suggested, in spite of its simplicity (the calculations of errors given in Table 1 were completed in about 4 hours), gives results of an accuracy which is practically not inferior to that of Borrass' method.

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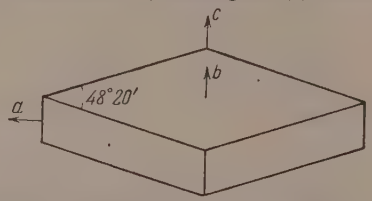
CRYSTALLOCHEMISTRY

X-RAY ANALYSIS OF THE CRYSTALLINE STRUCTURE OF Na_2BeF_4

By G. S. JDANOV and N. G. SEVASTIANOV

(Communicated by A. N. Frumkin, Member of the Academy, 14. XII. 1938)

Na_2BeF_4* crystals obtained in the form of regular boats (figure) by crystallization from a BeF_2 and NaF solution with an excess of NaF were subjected to X-ray analysis, after Laue's method, which showed them to belong in Laue's class $D_{2h} - mmm$; this is in agreement with the results of goniometric analysis by Marignac (1), who has established that



one of the two crystalline modifications Na_2BeF_4 refers to the rhombic-bipyramidal class with a ratio of the axes $a : b : c_{cryst} = 0.8243 : 1 : 0.3693$.

A measurement of the identity periods along the principal axes of the crystal carried out according to the exographs of rotation [100], [010] and [001] has given

$$a = 10.9\,\text{Å}; \quad b = 6.6\,\text{Å}; \quad c = 4.9\,\text{Å}; \quad v = 352\,\text{Å}^3.$$

From the X-ray measurements $a : b : c_{X\text{-ray}} = 1.65 : 1 : 0.74$, which points to the necessity of reducing the axial scale to half of its length b, obtained from crystallographic data. In such a case $a : b : c_{cryst} = 1.649 : 1 : 0.739$ is in good agreement with $a : b : c_{X\text{-ray}}$.

The pycnometrical density of the Na_2BeF_4 crystals is $\sigma_4^{20} = 2.458$ in aniline; $\sigma_4^{20} = 2.451$ in ether; hence taking $\sigma_{pycn} = 2.45_5$, we find the number of molecules in the unit cell:

$$Z = \frac{cv}{Mm_u} = \frac{2.45 \times 352}{131 \times 1.66} = 3.97 \approx 4.$$

The Karpov Physico-Chemical Institute.
X-ray Laboratory.

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* The Na_2BeF_4 crystals have been placed at our disposal by A. V. Novoselova, of the Moscow State University, under whose supervision the student Zhasmin has made the density determination of these crystals and to whom our gratitude is due.

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BIOCHEMISTRY

TRITICUM DURUM AND *VULGARE* DISTINGUISHED AFTER THEIR PROTEIN PROPERTIES

By M. I. KNYAGINICHEV and J. K. PALILOVA

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The morphological characters of a wheat grain since a long time enable the taxonomists to refer it correctly to the species it belongs to. But it is not so with its biochemical characters which, as far as we are aware, have not yet been discriminated according to different wheat varieties. We are lacking any method which would afford the possibility for such differentiation, because we possess but a quite insufficient knowledge as to the structure of the proteins and starch—those high-molecular substances which constitute the chief reserve of the seed.

Among the numerous varieties of the crop in question, two exhibit most striking differences in the physico-chemical properties of the complex of their gluten proteins, viz., soft wheat (*Tr. vulgare*) and hard wheat (*Tr. durum*). These differences become apparent both in their baking qualities and in the way they respond to the action of different oxidizers, especially, to bromate ($KBrO_3$) added in weak concentration ([1]). Whether the action of the latter is favourable to the quality of bread or otherwise should be considered doubtful ([2]). Many data, however, have now been accumulated which in the first line bear witness that in the process of evolution soft wheat and hard wheat have been differentiating most intensively, at least as regards the structural peculiarities of the protein. Our investigation, which embraced 11 varieties whose seeds were supplied from different localities, has also shown the soft and hard wheats to exhibit the greatest differences between each other, in whatever ecologo-geographic zone they may have spread in mass. No such striking differences were observed in other varieties, and, with regard to the principal physical properties (elasticity) of the gluten, for instance, they might be referred to soft wheat, which showed a very wide range of variation in respect of this character.

This must be interpreted to mean that in the process of evolution the differentiation of reserve matter in seed failed to keep a strictly parallel course with the differentiation of morphological characters.

In the present work we made an attempt at establishing the mobility of the gluten jelly of proteins from different wheats under the action of some washing liquids. For that purpose the gluten of each of the varieties tested was washed out by one of the following liquids: 1) distilled water; 2) 0.001% solution of bromate; 3) 50% solution of glycerine; 4) 10% solution of sodium salicylate. The gluten thus obtained was stretched over plates to form a thin layer and dried in air at room temperature. This method of drying is known to produce no appreciable change in the properties of the gluten ([3]). In two days it dried to such an extent, as to be easily ground in a mortar or ball mill. It should be mentioned here that after the gluten was washed out

with glycerine there followed its washing with distilled water. As it was to be expected [4], we failed in washing out the gluten with 10% solution of sodium salicylate, and with the solution of glycerine its yield was by 50—60% less than in the case of water or bromate solution.

In order to study the mobility of the complex of gluten proteins we successively extracted the gluten, dried and ground in the ball mill, with a 5% solution of potassium sulphate and 70% ethyl alcohol; the fraction soluble in alkalies was estimated from the difference. For the test we took wheat varieties grown at the Pushkin station of the All-Union Institute of Plant Industry near Leningrad. The results obtained from the analysis of the gluten are summarized in Table 1.

Table 1

Variety of wheat	Washing liquid	% of N in gluten	Content in % to total nitrogen in gluten			Ratio of glutenin to gliadin	
			Globulin	Gliadin	Glutenin	Abs.	Resp.
Triticum durum gr. *hordeiforme* 0189	Water	13.25	11.3	28.6	60.1	2.10	126
	0.001% solution of $KBrO_3$	12.90	8.1	34.4	57.5	1.67	100
	50 % solution of glycerine	12.50	9.1	30.8	60.1	1.95	117
Triticum vulgare gr. *graeco-rossicum* 0280	Water	13.58	8.0	12.9	79.1	6.13	381
	0.001% solution of $KBrO_3$	12.80	5.2	35.2	56.6	1.61	100
	50% solution of glycerine	13.50	6.8	33.3	59.9	1.80	112

It may be seen from the table that the ratio of glutenin to gliadin varies greatly with the change of the liquid used in washing the gluten. This is especially conspicuous in the case of bromate solution. Gluten proteins in a seed of the soft wheat are thereby undergoing much greater changes compared to those of the hard wheat. As to the ratio of nitrogen, we find it to change but slightly according to the variety; nor was it affected materially by the change of the liquid. The fact that the decrease of nitrogen is rather small in the gluten, can be explained by partial desamination of proteins which may possibly account for the differences in solubility properties.

The differences between hard and soft wheats in regard to the mobility of the protein complex of the gluten will not vanish after the plants have been supplied with liberal ration of fertilizers * (Pushkin Station of All-Union Institute of Plant Industry, yield of 1937), though they are considerably reduced in that case (Table 2).

Here too, we noticed considerable increase of glutenine gliadine ratio in the gluten of soft wheats, as compared to that in hard wheats.

We can thus state that if growth and development of the seed induce quite important changes in the structurel peculiarities of the proteins, never-

* Nested planting in pots with subsequent transplantation in field and reiterated introduction of fertilizers at different periods of growth. 1 g seed yielded 500 g. Plumpness of grain, markedly reduced in *Hordeiforme* (18%—to 71.5%), but near to norm in *Erythrospermum* 0841—69%.

Table 2

Variety of wheat	Washing liquid	% of N in gluten	Content in % to total nitrogen in gluten			Ratio of glutenin to gliadin	
			Globulin	Gliadin	Glutenin	Abs.	Resp.
Triticum durum gr. *hordeiforme* 0189	Water	14.72	4.7	30.4	64.9	2.13	122
	0.001% bromate solution	14.39	4.8	34.4	60.8	1.74	100
Triticum vulgare gr. *erythrospermum* 0341	Water	15.34	3.3	25.4	71.3	2.81	142
	0.001% bromate solution	14.91	3.1	32.5	64.4	1.98	100

theless there exist inherent differences between the species in question as regards the mobility of the protein complex. Considering the polymorphism of the hard and especially the soft wheat varieties, we can say a priori that the difference observed will be more strongly expressed in some of the varieties than in others, be it that they have grown and developed under equal conditions.

On the other hand, may hard and soft wheats have grown under different ecological and geographical conditions, their grain invariably shows differences in the solubility of the reserve proteins. Table 3 presents the results of the analysis of whole grains reduced to meal, taken from plants grown in different localities of this country in 1936.

Table 3

Variety of wheat	Locality	% of nitrogen in grain	Content in % to total nitrogen in grain			Ratio of glutenin to gliadin	
			Globulin	Gliadin	Glutenin	Abs.	Resp.
42-chromosome wheats:							
Triticum vulgare gr. *erythrospermum* 0341; origin from Saratov	Dnepropetrovsk	3.02	29.8	35.1	35.1	1.00	100
	Pushkin	2.75	29.8	32.7	37.5	1.15	115
Triticum sphaerococcum v. *tumidum*; from India; № 23824 in the cat. of VIR (All-Un. Inst. of Pl. Ind.)	Dnepropetrovsk	3.51	26.5	39.3	34.2	0.87	100
	Pushkin	2.98	24.2	39.3	36.2	0.92	105
Triticum spelta v. *caerulescens*; from Spain; № 20538 in the cat. of VIR	Dnepropetrovsk	3.99	25.6	31.6	42.8	1.35	100
	Pushkin	2.98	29.2	31.2	39.6	1.27	94
28-chromosome wheats:							
Triticum durum gr. *hordeiforme* 0189; from Saratov	Dnepropetrovsk	3.21	30.2	34.0	35.8	1.06	100
	Pushkin	2.57	29.2	29.2	41.6	1.43	135
Triticum durum v. *arraseita*; from Abissinia; № 19565 in the cat. of VIR	Dnepropetrovsk	3.15	28.6	36.2	35.2	0.97	100
	Pushkin	3.42	26.3	29.2	44.4	1.52	157

When grown outside of the black-soil zone (Pushkin), hard wheats, as is seen from this table, show the ratio of glutenin to gliadin considerably increased compared to soft wheats. The two other species belonging in the group of soft 42-chromosome wheats—*sphaerococcum* and *spelta*—also reveal this character. Their ratio between these protein fractions has a narrow range of variation both in the north and south of this country.

We have to point out here that hard wheats, *Tr. durum* v. *arraseita* № 19565 gives a gluten which in regard of its physical properties is strikingly different from the hard wheats of steppe type, such as *Hordeiforme* 0189, for instance. It is comparable only to soft wheats of inferior quality (not elastic and very weak). We are therefore not inclined to attach any importance to the ratio of glutenin to gliadin as the index of wheat quality, the more so as the real existence of these two proteins seems doubtful to us. We resort to the solubility character because other simple methods are wanting which might be used to detect the mobility of the complex of gluten proteins in different wheat species.

That the same species and varieties respond so differently to a similar change of growth conditions should, it would seem, be ascribed, in the first instance, to their specific requirement as to the temperature and humidity while in the stage of seed ripening. It is a well established fact that the ripening of the seed in the black-soil zone takes place under reduced temperatures and enhanced humidity of soil and air compared to the south regions. We can refer to the grain from the hard wheats grown in high mountain localities of Pamir (2700 m above sea level) which contained 1½—2 times less gliadin than that from principal wheat regions.

As to the question of what are the peculiarities in the structure of proteins which determine the way they dissolve in different solvents, we cannot expect it to be solved until after the specific structure of protein has been established for each of the various wheat varieties as well as the methods to determine those structures.

The data reported here entitle us to the following conclusions:

1. Differences between hard and soft wheats as reflected by the glutenin/gliadin ratio in the gluten washed out with various liquids bear witness of the different structure of the complex of gluten proteins in these two species of wheat. Though considerably smoothed out, their differences cannot be extirpated by agricultural technique.

2. Soft 42-chromosome wheats (*Tr. vulgare*, *Tr. sphaerococcum*, *Tr. spelta*), grown both within and without the black-soil zone, show practically invariable ratio of glutenin to gliadin in their grain. Hard wheat, however, when grown in the black-soil zone, yield a grain with markedly increased ratio between these proteins.

3. The study of protein complexes in the gluten isolated by some of the various washing liquids or otherwise has proved a promising method in attacking the problem of differentiation of wheat species, according to their protein properties.

Biochemical Laboratory.
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GENETICS

MASS PRODUCTION OF TETRAPLOID FLAX PLANTS BY COLCHICINE TREATMENT

By A. N. LUTKOV

(Communicated by N. I. Vavilov, Member of the Academy, 9. XII. 1938)

The first tetraploid plants of flax, *Linum usitatissimum* (L.) Vav. consp. nov. ssp. *mediterraneum* Vav. et Ell. (1), were obtained by us in 1937 as a result of high-temperature treatment of the zygote (2). During our cytological analysis of plants grown in the spring of 1938 from seeds collected from the heat-treated material of our 1937 experiments, we found tetraploid plants in two forms of *L. usitatissimum* (L) Vav. consp. nov. ssp. *eurasiaticum* Vav. et Ell.—semi-winter flax K. 2026 (Azerbaidjan)—12 plants; long-fiber flax (variety «Pobeditel»)—20 plants—and also in the previously described large-seeded Mediterranean form of seed flax, R. 302 (Morocco)—8 plants.

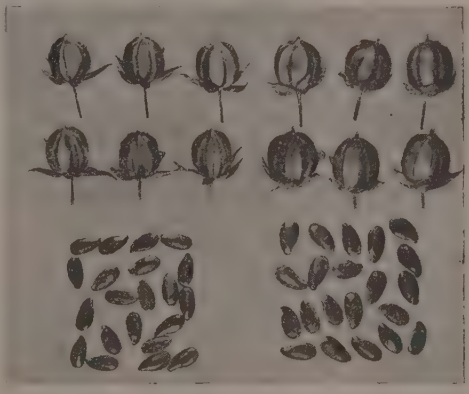

Fig. 1. Comparative sizes of capsules and seeds of diploid (left) and tetraploid (right) form of flax: K. 302 (Morocco).

All the tetraploid plants of these various forms were characterized by increased size of capsules and seeds (Fig. 1). The frequency of their occurrence in experiments with high-temperature treatment of the zygote ranged from 2 to 3.

After the publication of the paper by Blakeslee and Avery (3), this spring we expanded our experiments on chromosome doubling in flax by including treatment with the alkaloid colchicine. For these experiments we took the following 15 forms of cultivated flax ($2n=32$):

I. Ssp. *eurasiaticum* Vav. et Ell. proles *elongata* Vav. et Ell. Selected varieties of long-fiber flax: DS-30, DS-33, DS-2902 (Institute of Plant Industry); hybrid forms: GDS-1 and GDS-3 (Institute of Plant Industry); and also a fiber type of pink-flowered flax from Vilmorin (Institute of Plant Industry, Cat. № 275); «Pobeditel», «Tekstilchik», and «Pskov Improved» (Leningrad Flax Station); semi-winter flax, K. 2026 (Azerbaidjan) with branched,

candelabra-like stems (proles *prostrata* Vav. et Ell.); Krasnokut seed flax № 420 (proles *intermedia* Vav. et Ell.).

II. Ssp. *transitorium* Ell. Seed flax: № 1647 (Institute of Plant Industry) and K. 303 (Argentina).

III. Ssp. *mediterraneum* Vav. et Ell. Large-seeded Mediterranean seed flax: K. 302 (Morocco) and K. 265 (Egypt).

In addition, we included two wild forms of flax—*L. usitatissimum* (L.) Vav. consp. nov. ssp. *angustifolium* Vav. et Ell. ($2n=32$) and *L. perenne* L. ($2n=18$), and also an ornamental form of red-flowered flax, *L. grandiflorum* Desf. ($2n=16$).

The colchicine was applied to germinating seeds and to the growing tips of plants. In the first case we placed in an aqueous solution of colchicine (0.2%) for a period of 6 to 48 hours germinating seeds with their unfolding cotyledons; the roots, however, were not immersed, but covered

a *b* *c*

Fig. 2. Effect of treating growing tips with colchicine: *a*, control plant; *b*, *c*, types of changes induced by treatment.

with moistened filter paper. When the growing tips of plants were treated with colchicine, drops of uncongealed colchicine solution (0.05, 0.1 and 0.2%) in 0.6% agar-agar were applied to the tips.

The direct effects of the colchicine treatment of germinating seeds were: a marked swelling of the hypocotyl of the seedlings, a retardation in the development of the plants, and changes in their morphology, particularly a change in the structure of the leaves, which in a number of plants were shorter and broader. As development proceeded, the sharpness of the morphological changes was further intensified. Sometimes the entire plant was altered; sometimes only separate shoots. Frequently plants remained dwarfed till the end of the vegetative period.

The effect of treating growing tips was even more marked. Only a few days after the treatment there was already observed a decided retardation in the development of the plants. The upper part of the stem became club-shaped. The leaves grew shorter and thicker, and their colour changed from green to pale-green with speckles. The surface of the leaf blade became somewhat scabrous. In some cases the uppermost part of the plant resembled a rosette of leaves. Subsequently the tip either withered away or renewed growth, giving rise to a new shoot (Fig. 2).

Very frequently, when the tip of the stem had withered away, in the zone adjacent to the place of treatment there began to form in the axils of the shortened leaves deformed buds, which gave rise to morphologically altered shoots. The buds borne on such shoots also proved to be markedly

altered, sometimes attaining a gigantic size and exhibiting various degrees of deformation. The flowers which developed from such buds were distinguished from flowers of diploid forms both in size and in structure. In a number of cases the flowers, instead of having 5 petals, had 6, 7, or even 9 petals.

Considering the differences in the sizes of flowers in diploid and tetraploid flax, established by us in our earlier experiments (2), it is probable that in the present case most of the altered shoots are tetraploid, while those having flowers with 8—9 petals may be octoploid or characterized by some other change in the chromosome complex.

An analysis of the pollen, both of flowers produced on morphologically altered shoots and of those borne on normal shoots, showed in a number of cases an increase in the size of the pollen grains (length of diameter), as compared with the pollen of control forms, and also very marked gradations as regards the percentage of abortive pollen. For example, the size of pollen grains in diploid forms of fiber flax (variety «Pobeditel») ranged from 45.9 to 68.8 μ, while that of pollen grains of flowers on altered shoots reached 84—91.8 μ, indicating that these shoots were tetraploid. Similarly, in large-seeded forms of diploid flax the size of the pollen grains ranged from 61.2 to 76.5 μ, while that of pollen grains from altered shoots ranged from 91.8 to 114 μ. In control plants of *L. perenne* L. the pollen grains ranged from 61.2 to 84.15 μ in diameter, while the pollen grains of large flowers on altered shoots ranged from 99.4 to 107.1 μ. In narrow-leaved wild flax, ssp. *angustifolium* Vav. et Ell., the pollen grains did usually not exceed 53.5—61.2 μ in diameter, while in flowers on altered shoots the pollen grains attained a diameter as great as 84.15 μ.

Cases were frequently observed, when the percentage of abortive pollen in the first flowers of altered shoots was very high, but, as the development of the branches proceeded, this percentage gradually decreased, and, finally, almost no abortive pollen was formed. Sometimes flowers contained not only large pollen grains, but also pollen grains of the size usual for diploid plants and exceptionally small pollen grains.

Forms of flax used in experiment *	Duration of treatment (in hrs.)	Number of seeds treated	Number of plants obtained	Plants obtained (in %)	Number of tetraploid plants (determined by pollen size)	Tetraploid plants (in %)
Seed flax, VIR (Institute of Plant Industry), Cat. No 303 (Origin: Argentina)	6	25	24	96.0	15	62.5
	12	20	18	90.0	10	55.5
	18	25	17	68.0	11	70.5
	24	14	11	78.0	9**	45.4
	36	15	14	93.0	9***	42.8
	48	19	5	26.5	3	60.0
Hybrid form No GDS-1 (VIR)	24	18	13	72.5	8	61.5
	48	30	6	23.3	5	83.3
Large-seeded form of seed flax, VIR, Cat. No265 (Origin: Egypt)	24	21	16	76.1	15****	75.0
	48	13	3	23.0	3	100.0

* More detailed data on botanical classification are given at the beginning of this paper. ** Of which 4 were octoploids. *** Of which 3 were octoploids. **** Of which 3 were octoploids.

A number of plants exhibited a complex chimerical structure. The percentage of abortive pollen in polypetalous flowers reached 85% and over, but the pollen grains in such flowers which developed normally proved to be gigantic (as large as 124.4 μ) and presumably corresponded to the type of pollen grains of octoploid plants.

In the table are given data for several forms of flax with respect to the occurrence, as a result of colchicine treatment, of plants with enlarged pollen grains corresponding to the size of the pollen of tetraploid forms.

These data show how frequent is the occurrence of tetraploid plants in colchicine experiments, the rate reaching as high as 83.3% and over when germinating seeds are treated (table). An equally high rate of occurrence of tetraploid shoots was observed by us, when the growing tips of plants were treated with colchicine. The larger size of the seeds and capsules pro-

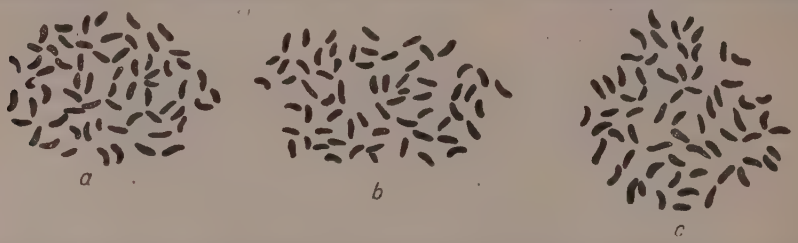

Fig. 3. Somatic plates of chromosomes of tetraploid forms of flax ($2n=64$): *a*, fiber flax, hybrid form GDS-3; *b*, seed flax No 1647; *c*, semi-winter flax, K. 2026 (Azerbaidjan).

duced by such plants, accompanied by a decrease in the number of seeds per capsule, confirms the fact that these were actually tetraploid forms. The plants which we classified, by the size of the pollen, as octoploid proved to be sterile.

A preliminary cytological analysis of the progeny of those plants which set seeds has shown that there is almost complete agreement between the data presumed on the basis of a study of pollen size and the data obtained by a study of the chromosome number. In all 15 cultivated forms we found plants with a doubled chromosome number. In Fig. 3 we show somatic plates of chromosomes for a few of the tetraploid forms of the different types of fiber and seed flax.

Tetraploid forms of one variety of flax, induced by colchicine treatment of the seeds, were also obtained this summer by M. Simonet ([4],[5]), who, on the basis of a preliminary study of meiosis of his tetraploid plants, has established their haploid chromosome number as 30.

Due to the small number of plants of the wild species of flax [*L. usitatissimum* (L.) Vav. consp. nov. ssp. *angustifolium* Vav. et Ell. and *L. perenne* L.] and of the ornamental form (*L. grandiflorum* Desf.), included in our experiment, and due to the difficulty in getting capsules to set in the two last-mentioned species, as a consequence of heterostyly (in the experiment there was included only one plant of *L. grandiflorum* Desf., which did not produce any seed), we did not make chromosome counts in the progeny of the colchicine-treated plants of these species, but the data as to the size of the flowers and pollen on certain of their shoots indicate that in these species too there occurred chromosome doubling.

On the basis of the possibility of increasing the crossability of species by doubling their chromosome number, which has been established by earlier genetic investigations([6]), we have undertaken experiments on the hydridization of tetraploid *L. perenne* L. with tetraploid forms of cultivated fiber flax, with the aim of obtaining hybrids, which in structure, we believe,

should be amphidiploids between these two species and should be perennial. In addition, we have begun experiments on crossing tetraploid *L. perenne* L. with diploid forms of cultivated flax.

In connexion with the increase of anatomical elements in plants as a result of the doubling of their chromosome set, it appears of great interest to make a study of the technological qualities of tetraploid forms of fiber flax, which for the variety «Pobeditel» may be undertaken in a preliminary way, since we have started the propagation of tetraploid forms of this variety.

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GENETICS

ACENAPHTHENE-INDUCED POLYPLOIDY IN *NICOTIANA*

By F. A. FATALIZADE

(Communicated by N. I. Vavilov, Member of the Academy, 5. XII. 1938)

Despite the great theoretical and practical importance of polyploidy, there was until recently no method assuring the success of work on the experimental production of polyploid plants. About a year ago Blakeslee and Avery (1) described a method of obtaining polyploid forms in plants by treatment with colchicine, a method far more effective than those previously in use (2, 3, and others).

Shmuck (4), basing his conclusions on the chemical nature of colchicine and acenaphthene and their similar external effect on wheat seedlings, suggested the possibility of inducing polyploidy by treatment with acenaphthene. Investigations by Navashin (5) and Kostoff (6 and others) have made this supposition of Shmuck's more probable.

In the present paper are given the results of experiments conducted in 1938 (see table) on inducing polyploidy in *Nicotiana* by treatment with acenaphthene and also some details regarding the amphidiploids *N. rustica* var. *scabra* × *N. paniculata*.

Young seedlings from seeds sown on filter paper in Petri dishes were sprinkled with acenaphthene crystals and subjected to their action for 4—5 days. After the treatment only those plants which were markedly altered morphologically (thickened) were transplanted. It was necessary to make

Species and hybrids	Duration of treatment (days)	Number of plants			Number of plants flowering				Number of control plants
		transplanted	died	not flowering	total	with normal chrom. number	with doubled chrom. number	chimerical	
Tabac. × *silvestris*	5	18	16	2	—	—	—	—	5
Rustica × *paniculata*	4	27	7	1	19	5	12	2	10
Glauca × *tomentosa*	5	10	10	—	—	—	—	—	3
N. paniculata . .	5	27	9	2	16	11	5	—	5
F_2 [*paniculata* × × (*paniculata* × × *solanifolia*)] .	4	36	11	4	21	14	7	—	5

Note. No polyploids were found among the control plants.

such a selection, because the action of the crystals, due to their limited number, might not have extended to all the seedlings.

The seeds from each capsule were divided into two parts. One part was treated with acenaphthene; the other served as a control. Both sets of plants were grown under the same conditions. The chromosome numbers were determined in pollen mother-cells during the study of meiosis.

The results of the experiments are summarized in the table.

F_1 *N. rustica* × *N. paniculata* Hybrids. Such hybrids have been obtained and studied by many investigators. It is rather difficult to cross them with the parental forms, and they are highly self-sterile. Singleton(7) found the self-fertility of these hybrids to be less than 1%. Our hybrids, the mother plants of which were *N. rustica* var. *scabra*, *N. rustica* var. *brasilica*, and the variety «Cheremsha», did not produce any seed from repeated self-pollinations during three years (1936—1938). In the case of open pollination most of the flowers dropped without setting any capsules; a very few seeds were obtained from occasional capsules. S. A. Eghiz has informed us that during the course of many years he did not obtain a single plant from self-pollination of such F_1 hybrids, many different forms of *N. rustica* having been taken as mother plants.

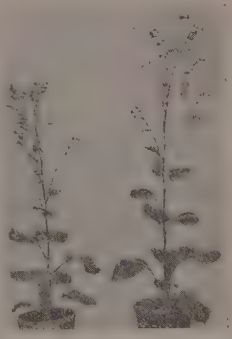

Fig. 1. Left, F_1 *rustica* × *paniculata* (control); right, amphidiploid.

In our present experiments the control plants of *rustica* × *paniculata* did not differ in any respect from such hybrids described by many other investigators (Fig. 1). They had 36 as their chromosome number and were self-sterile (Fig. 2). No seeds were obtained from self-pollination of 50 flowers of the control plants (5 flowers on each plant).

The *N. rustica* var. *scabra* × *N. paniculata* Amphidiploids. As may be seen from the table, 27 F_1 *rustica* × *paniculata* hybrids were transplanted after treatment with acenaphthene. Of the 19 plants which flowered 5 had 36 as their chromosome number, and did not differ at all from the control plants, except for the fact that their first leaves were somewhat deformed. The percentage of pollen grains staining in aceto-carmine ranged from 3 to 7. By self-pollination (4 flowers per plant) no seeds were obtained.

Twelve of these plants proved to be amphidiploids, and produced—by self-pollination, crossing inter se and open pollination—as many as 200 seeds per capsule. The percentage of pollen staining in aceto-carmine ranged in different plants from 69.6 to 85.4 (Fig. 3). Morphologically the amphidiploids were distinguished from the control plants by larger size and larger and thicker leaves (Fig. 1). The flowers were scarcely any longer, but the corolla tubes were considerably broader than those of control plants.

Two plants proved to be chimerical, one of them having only a single amphidiploid shoot and the other having several shoots with fertile flowers and several with sterile flowers. The chromosome number of the amphidiploid shoots was 72, and the percentage of pollen staining in aceto-carmine was as high as 85.4. The chromosome number of the other shoots on these same plants was 36, and the percentage of pollen staining averaged only about 3.

A cytological investigation of the amphidiploid plants and shoots showed some irregularities at meiosis. At first anaphase lagging of chromosomes was sometimes observed, but at second anaphase such lagging was very

rare. At first metaphase the number of chromosome bodies ranged from 32 to 36, in most cases 36 (Fig. 4). At second metaphase the following chromosome distributions occurred: 36+36, 35+37 and 34+38; the 36+36 distribution was the most frequent (Fig. 5).

Crossability of the Amphidiploids. When the amphidiploids were crossed with *N. paniculata* (either direct or reciprocal crosses), the flowers usually dropped without setting capsules, and the few capsules

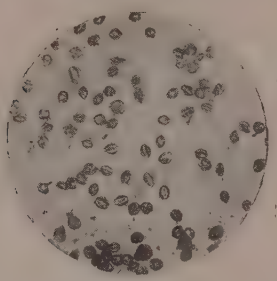

Fig. 2. Photomicrograph of F_1 *rustica* × ×*paniculata* pollen (control).

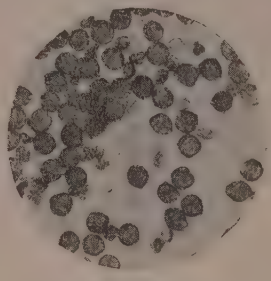

Fig. 3. Photomicrograph of pollen of amphidiploid.

which did form, despite their normal external appearance, contained only a mass of empty seeds. There were very few normal-appearing seeds. When, however, they were crossed with tetraploid *N. paniculata*, likewise obtained by treatment with acenaphthene, as many as 80 seeds per capsule were formed, and these proved to germinate normally. When crossed with *N. rustica*, in either direction, there was obtained as many as 150 normal-appearing

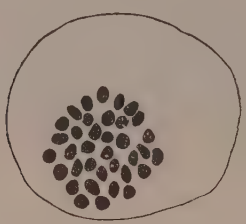

Fig. 4. First metaphase of pollen mother-cells with 36 chromosome bodies.

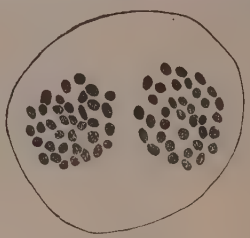

Fig. 5. Second metaphase of pollen mother-cells (36+36 distribution).

seeds per capsule, but they had a very low percentage of germination (only 5 out of 130 seeds germinated).

From numerous crosses with *N. glauca* there were obtained in all only a few plump seeds, most of the seeds being empty. Crosses with *N. Bigelovii* and *N. glutinosa* were not successful. By pollination of the amphidiploids with *N. Rusbyi* pollen (3 flowers) only one plump seed was obtained. By pollinating them with pollen from *N. acuminata* var. *parviflora* there were obtained as many as 160 plump seeds per capsule, while crosses with *N. acuminata* var. *grandiflora* were entirely unsuccessful.

N. rustica×*N. paniculata* amphidiploids have been obtained by several investigators ([7], [8], [9]) in the F_2 from self-pollination of F_1 hybrids, as a result of the fusion of unreduced gametes. They were also obtained by Kostoff ([9]) by a gradual accumulation of genoms. Their occurrence in F_1, however, has not previously been reported.

Despite the fact that in the case of our amphidiploids the mother plant belonged to a different variety of *N. rustica* and that they were obtained vegetatively, in contrast to the amphidiploids obtained generatively by the investigators cited, the data obtained are quite similar.

As is clear from the foregoing, our data prove the possibility of inducing polyploidy by treatment with acenaphthene, and thus confirm the conclusions of Shmuck(4), Navashin(5), and Kostoff(6).

I wish to express my thanks to N. I. Vavilov and Dr. S. A. Eghiz for their valuable suggestions during the course of the investigation.

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PLANT PHYSIOLOGY

RELATIONSHIP BETWEEN PHOTOPERIODISM AND DROUGHT RESISTANCE OF PERENNIAL PLANTS

By B. S. MOSHKOV

(Communicated by N. I. Vavilov, Member of the Academy, 11. XII. 1938)

Drought resistance of plants as well as their frost resistance is essentially determined by the whole of the physiological processes going on before, and not only by those which are taking place after drought, respectively frost, has set in. After the frost resistance of plants had been found to be one of the sides of their photoperiodic reaction, it was natural to suppose that the same might be true of the drought resistance. This theoretical consideration was moreover supported by the anatomico-morphological changes which, within the range of one clone and variety, created now a xeromorphous now a hydrophilic structure, according to the photoperiods the plant was given. In order to obtain experimental evidence of the connexion between the resistance of plants to drought and the photoperiodic conditions of their vegetation in the years 1934 and 1935, we set up laboratory experiments in which soil drought was created artificially for some woody species which while growing received different photoperiods. All the plants under test were grown out-of-doors in pots with optimal soil humidity, and not until watering was eliminated were they transferred to wilt in the hothouse. Before wilting set in, all the pots with the plants were immersed in water, which completely saturated the soil, whereupon the water supply was cut off till either the end of the experiment or the first wilting.

American cherry (*Prunus Besseyi*), locust (*Robinia pseudacacia*), lemon and tea were taken for the experiment.

Cherry was set in twelve cm pots by the end of April, one seed in each pot. Seedlings appeared towards the middle of May. Then the plants were divided into three groups. Group 1 was given continuous illumination; group 2, 14-hour days; group 3, 9-hour days. On August 15 10 plants from each of the photoperiodic variants were transferred to the hothouse and the water supply was cut off. During drought time the plants received natural photoperiods. At the time the plants were starting the wilting test, i. e. on August 15, the seedlings of *Prunus Besseyi* had nearly the same height and foliage in all variants, and their growth was almost completed. Their appearance impressed the idea that the species is but little inclined to respond to the change of photoperiodic conditions. Nevertheless, 15 days later, as it may be seen from Fig. 1, wilting appeared in the plants of variant 1 and 3, while those which had received 14-hour days throughout the vegetation period remained quite normal. Wilting manifested itself not only in the

leaves being rolled and withered, but also in that the tops of the seedlings had lost turgor (Fig. 1).

It was not until 10 days more, i. e. 25 days from the elimination of watering were passed, that the plants of the 14-hour day variant became wilted. By this experiment evidence has been furnished of the plant's resistance to soil drought being greatly dependent on the day length of vegetation period. We may therefore conclude that there exist optimal and critical photoperiodic conditions for the plant to obtain its maximum drought resistance, as it is the case with other sides of its life activity.

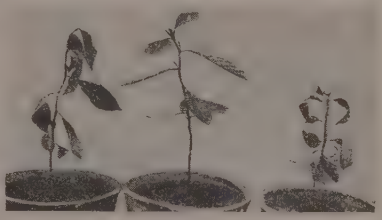

Fig. 1. Condition of seedlings of *Prunus Besseyi* 15 days after elimination of watering. Left, continuously illuminated plant; in the middle, 14-hour day plant; right, 9-hour day plant.

The locust *Robinia pseudacacia* L. was grown in 16 cm pots, two plants in each pot, being also given different day lengths. During the period preceding the outset of drought the plants were kept in beds inclosed in small cabins which served to curtail the day length. Drought set in on August 15, when 3 pots from each of the variants (13, 14, 15 and 16-hour photoperiods) were transferred to the hothouse. 15 days after water supply had been stopped, i. e. on August 31, the plants of 16 and 15-hour variants not only wilted, but had most of their leaves dried and fallen off, whereas the plants of 14 and 13-hour variants were in no way affected with wilting (Fig. 2).

In this experiment the affected plants of 16 and 15-hour variants differed greatly from 14 and 13-hour plants, though the difference between the two middle variants was only one hour. The latter finished growing when the seedlings of the former still continued to grow. The height of the 13 and 14-hour plants was only half and their foliage was poorer compared to those which were given 15 and 16-hour days. Their smaller evaporating surface accounts for the lesser amount of water being lost by them within 15 days. Further observations, however, have shown that 14-hour plants are capable to stand such low content of water in soil as is far below that indispensable for the life of 15-hour plants. And so great a difference may not be put down to the reduced evaporation alone.

Fig. 2. Locust *Robinia pseudacacia* L. 15 days after the outset of soil drougt. Rightwards: *1*, 16-hour day plant which suffered no wilting (the rest of the plants belong to the variants affected with wilting); *2*, 16-hour day plant; *3*, 15-hour day plant; *4*, 14-hour day plant; *5*, 13-hour day plant.

Morphological and anatomical structure of the locust plants grown under 13 and 14-hour illumination approached them to aeromorphous types, while with 15 and 16-hour day length they had rather a hydrophilic structure. The number of stomata, the amount of waxy coat, the thickness of leaf cuticule, the soberization of shoots etc. were in different degree expressed in them. Whether these are the structural peculiarities which should be considered decisive or otherwise is however uncertain, since no such differences have been observed in cherry. Characteristic is that after water was

withheld from the plants during a definite period (ranging between 15 and 30 days) they invariably became wilted, and not a single case was observed where they would shed leaves normally. But if subjected to reiterated wilting they behaved quite differently. Among the experiments of 1934 there was a variant in which locust plants given 15-hour days underwent soil drought many times and not one time, as the plants of the other variants. The plants of this variant were also transferred to the hothouse when deprived of water supply. After the first wilting, as soon as their tops had lost turgor, they were given water, which increased the humidity of soil up to 75%. Then the water supply was interrupted again until first signs of wilting appeared anew (the top lost turgor), whereupon the supply of water was restored. This procedure being repeated again and again, the leaves of the plants yellowed and fell off in their normal way after the plant had already completed its growth which process engaged but 3—4 weeks. Consequently, the plants through continuous and protracted wilting are led to destruction which sets in with the drying off of their leaves and tops before growth is completed and normal shedding of leaves can take place; on the other hand, they grow and shed leaves normally if weak wilting and watering alternate with each other. The plants seem thus unable to resist the steadily increasing drought of soil, but the rapid rhythm of recurring soil humidity induces in them protective qualities, which make normal growth and leaf shedding possible.

It is worthy to note that in Sukhumi we were successful to observe the same phenomenon in the evergreen plants of tea and lemon.

These evergreen species, as well as the deciduous ones, completed growth quickly and shed yellowed leaves when wilting and watering were carried on in succession. It may be considered that there is no essential difference between deciduous and evergreen species. The latter can shed and restore their foliage, while the former easily turn into evergreens. In the case of protracted soil drougth the leaves of the citrus plants dried, but remained on the trees. The highest resistance to soil drought was observed in the lemon and tea given short, 8—10-hour days. Best growth in lemon was induced with 12-hour day length and the resistance to drought was higher than in the variants with greater day length, which none the less were behind in growth.

The resistance to drought of any cultivated variety is no doubt dependent not only on photoperiodic conditions of the experiment, but also and for the same reason on the geographic latitude of its cultivation.

Reiterated wilting can be turned to account as a means to accelerate growth and leaf shedding even in evergreen plants, and this may prove profitable not only for their cultivation in hothouse but in field condition as well, since it will increase their resistance to cold which quality is of especial importance in irrigated regions, say, in those districts of Eastern Transcaucasia and Middle Asia which are frequently suffering drought.

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PLANT PHYSIOLOGY

SYMBIOSIS OF LEGUMINOUS PLANTS WITH NITROGEN ASSIMILATING BACTERIA AS DETERMINED BY PHOTOPERIODISM

By B. S. MOSHKOV

(Communicated by N. I. Vavilov, Member of the Academy, 11. XII. 1938)

On the spring of 1930 one-year old seedlings of locust *Robinia pseudacacia* L. were dug up from the beds where they underwent photoperiodic experiment in the year next before, and it appeared that there were no nodules with nitrogen assimilating bacteria on the roots of the short-day plants, while they were present in the controls, although in small number.

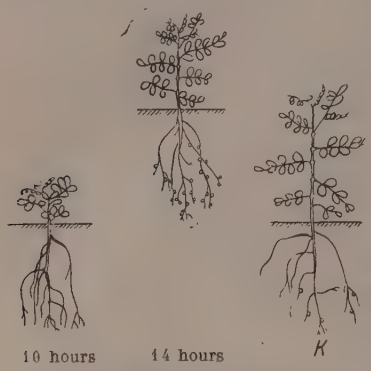
In the year 1930 locust plants were grown while being given natural day length (controls) and photoperiods of 14, 12 and 10 hours, respectively. In the fall of the same year part of plants from each variant were dug up to count the nodules. The latter were absent in the seedlings of 10 and 12-hour day, but the roots of 14-hour day seedlings abounded with nodules. Each of these plants had 25 nodules on the average. In the controls, induced with natural day length, their number was considerably smaller—no more than 5—7 nodules per plant. A certain connexion has thus been established between the photoperiodic conditions of locust growth and the presence on its roots of nodules with nitrogen assimilating bacteria (Fig. 1).

In the next year (1931) locust were grown in Rotmistrov boxes, being given natural, 14 and 10-hour days respectively. The roots, washed in fall, revealed the same dependence. In 14-hour day plants nearly all root fibrils bore nodules of various size. The latter were few in controls and entirely lacking in 10-hour day plants. The experiments of 1932 marked out the lower limits of photoperiodic conditions, unsuitable for the symbiosis of locust and nitrogen assimilating bacteria. This limit lies between 12-hour and 13-hour day length. These photoperiods go parallel with the absence of nodules and their presence, but in smaller number than when induced with 14-hour day length.

In the same year (1932) we experimented with another woody plant of *Leguminosae—Halimodendron argenteum* Fisch., which usually will not grow on its own roots in the northern latitudes of Moscow and Leningrad, unless it is grafted on *Caragana arborescens*, and then it thrives there well and even gives flowers and fruits. When *H. argenteum* is cultivated in the north, the nodules do not form, as a rule, on its roots and this was the reason why the respective bacteria were supposed to be absent in northern soils.

Being poorly provided with seeds of *Halimodendron argenteum*, we confined the experiment to two variants only—natural (control) and 12-hour day. The seedlings of the control variant grew very badly and finished with dying; no nodules were detected in their roots. The waste of seedlings given 12-hour day lengths was, on the contrary, insignificant and when they were dug up from the beds some nodules, very few indeed, were observed on their roots. It suggests itself the conclusion that other factors than the absence

of bacteria in northern soils prevent the nodules to form on the roots of *Halimodendron argenteum*. They should be sought in the unfavourable ecological conditions of the vegetation period among which an important place is assigned to the factor of photoperiodism. In the experiments referred to above, both on locust and *Halimodendron*, such photoperiodic conditions were found, under which nodules either form or may not form at all. Hence, those species represent such a type of plants where the symbiosis with nitrogen assimilating bacteria enter into their photoperiodic reaction and shows them by no means neutral, as regards this character too. There exists, however, another type, say soya, which, according to Eaton, forms nodules invariably whatever photoperiodic conditions may prevail during its growth (from 3 to 16-hour day length). Still more definite picture characteristic of the second type of leguminous plants has been discovered by the author in his experiments on peas. Some varieties of the latter formed nodules whatever the day length ranging between 5-hour day and continuous illumination. But the number of nodules per plant in those species varied considerably, according to the photoperiodic conditions. On ground of this character they cannot possibly be accounted neutral to photoperiodism.



Locust seedlings above their respective day lengths.

In all the experiments soil was taken from the same plot and hence contained the same species of bacteria. Similar results were obtained with sterile soil infected artificially with bacterial culture. Though our observations are few they entitle us to the following conclusions. The presence and number of nodules with nitrogen assimilating bacteria in the root of leguminous plants depends upon photoperiodic conditions prevailing at vegetation. As for many other sides of plant's life activity, so for their symbiosis with nitrogen assimilating bacteria there exist optimal and critical photoperiods which vary according to the species concerned.

Photoperiodic conditions of the growth of plants seem to determine their metabolism and therefore to create either optimal or unsuitable conditions for the bacteria to live in root tissues. Whether the same bacteria available in soil are able or not to penetrate the tissues of the root and live there is thus dependent on what photoperiods the host plant is given while growing.

The cosmic rôle of plants, frequently indicated by K. A. Timiriazev, and the significance of the daily rhythm of radiant energy for their life activity is once more brought out by the dependence we have established between the symbiosis of many leguminous plants with nitrogen assimilating bacteria and the photoperiodic conditions of growth.

The practical conclusion to be drawn from the facts referred to here is:

1. Adequate estimation of both mineral and organic supply vary for different localities of this country and require due consideration of photoperiodic conditions, which exert their influence upon relations between soil and plant through the activity of nitrogen assimilating bacteria.

2. The influence the leguminous plant concerned is apt to produce through nitrification of soil, varies with the photoperiodic conditions and, accordingly, with the geographic latitude.

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PLANT PHYSIOLOGY

PHYSIOLOGICAL CHARACTER OF CHANGES INDUCED IN MAIZE BY REMOVING MALE INFLORESCENCE (TASSELS)

By G. M. PSAREV

(Communicated by A. A. Richter, Member of the Academy, 5. XII. 1938)

The question as to the effect produced in maize by removing male inflorescence has more than once been discussed in literature. Most of the experimental efforts have centered about two points; the first was to clear up the morphological character and genetic nature of the anomalies resulting from the traumatism of plants's summit (1); the second, to establish whether a favourable effect on the productivity of the plant may be obtained by this operation [(2) and others].

It is in the second aspect that the problem has mainly been treated in agronomical literature, a considerable space of time being elapsed since the experimental work had started in this direction. By no means can we say, however, that sufficient answers have been obtained to a number of important questions, concerning not only the theoretical but even the practical side of the method of tasseling, and one of them though of prime importance to the agricultural practice, namely that of the way the removal of tassels affects maize's productivity, has as yet remained unsolved.

Very meagre is the literature devoted to the physiological study of the phenomena which are brought into play after removal of male inflorescence. The operation itself is called emasculation by most of the investigators [(2, 3) and others], who are inclined, it would seem, to draw a parallel between the phenomena called forth in plants by stripping of flowers and those observed in castrating animals. Yet it is now a fact well established by those Soviet workers who have been inquiring into the rôle of the leaf in the sexual development of the plant (4-9), that the regulative function in the sphere of plant's sexual activity is performed by the life activity of its green tissue—the leaf, rather than by its sexual organs. We can therefore no longer subscribe to the view that the processes incited in plants by taking away their flowers—in maize respectively by removing its male inflorescence—rest on the same theoretical ground with those which in animal world are connected with the removal of testicles.

In order to apprehend the physiological character of the processes induced by tasseling in the proper light, it is necessary to get a clear idea of the peculiar position of the sexual organs in maize. The latter is a monoecivus plant bearing both male and female flowers assembled in spikes of different form and situated at different places. The male spikelets are arranged in the form of a panicle, which terminates the development of the axial organ—

the stem; in the female inflorescence the spikelets are closely united to form a cob, which is a lateral axillary organ. The investigation concerned with the question under review had for object: 1) to reveal the influence the removal of the male (terminal) inflorescence exerts upon growth and development of the female inflorescence which is an axillary lateral organ; 2) to ascertain the physiological character of the change in plant's behaviour caused by taking away the tassels; 3) to establish a proper theoretical interpretation of the phenomenon analyzed.

The first and second items are to be considered in the present article.

The experiments described were carried on in vessels containing 9.5 kg of air-dry soil. One plant was grown in each vessel. The experiments refer to different times beginning with the year 1936, and it is only part of their results which we are going to report here.

Tasseling was performed at two times in accordance with the two periods in the development of the terminal inflorescence. The first removal was done when the development was possibly early, viz. when the terminal cone of the growing stem began differentiating into a reproductive organ. In the most of the varieties tested this became externally apparent by that the lower internodes of the stem began to grow longer.

In that case the operation consisted in cutting the quite differentiated terminal inflorescence out of the stem with a scalpel. This was not effected without considerable injury to the stem and leaves.

Table 1

Phenological Observations on Operated Plants

Variety and variant	Periods of development in days			
	from sprouting till flowering of male inflorescence	from sprouting till pushing of filaments (flowering of female inflorescence)	from pushing of filaments till full maturity	from sprouting till full maturity
1936				
Minnesota 13 extra:				
Tasseling at first time	—	58.25	41.0	99.25
» » second time	—	55.25	41.0	96.75
Control	59.1	62.10	36.7	98.8
Terskaja white No 400:				
Tasseling at first time	—	57.0	44.75	101.75
» » second time	—	52.2	40.40	96.6
Control	59.6	63.15	35.07	98.2
Liming:				
Tasseling at second time	—	69.0	38.25	107.25
Control	70.1	77.0	43.58	120.58
1937				
Minnesota 13 extra:				
Tasseling at the second time	—	53.2	40.8	94
Control	53.4	55.2	38.8	94

At the second time the male inflorescence was removed by hand when the panicle was pushing out from the leaf sheath.

Detailed observations on the experimental and control plants have shown tasseling to induce considerable alterations in the behaviour of maize which, first of all, manifested themselves in the development and growth of the female inflorescence and in how the leaves took colour, yellowed and aged. From the data referred to in Table 1 (experiments of 1936 and 1937) it may be inferred that in the plants operated the stigmata of the pistil (filaments) appear several days sooner compared to controls. The acceleration ranged within 2—7 days in Minnesota 13 extra, within 6—11 days in Terskaya white No 400, and was 8 days in Liming.

In many maize varieties grown under natural conditions an interval of varying degrees of duration separates the blossoming of male flowers

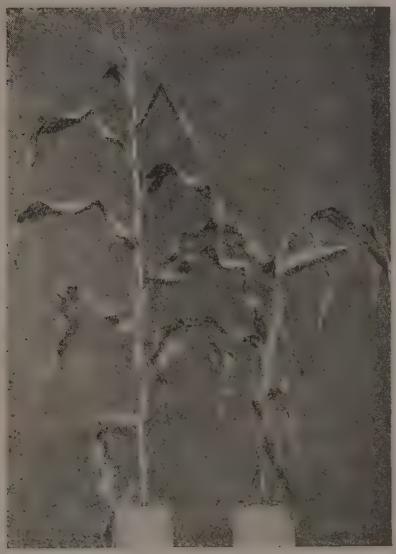

Fig. 1. Vessel № 3—experiment. Terminal inflorescence removed at the 1st date. Vessel № 7—control. Maize, variety Minnesota 13 extra.

Fig. 2. Terminal inflorescence removed at the 1st date. The plant has formed several (8) female inflorescences. Maize, variety Minnesota 13 extra.

from that of female ones. Now, the appearance of the female inflorescence is accelerated as soon as the male inflorescence is taken away, and the interval between the two flowering times in different plants is curtailed. This, in turn, ensures better fertilization of the female inflorescence and further development of the axillary cob proceeds more quickly.

This statement is substantiated by the representation of two plants (Fig. 1), one of which was tasseled at the first time. In face of the accelerated development of the axillary cob in experimental plants, the period which followed the appearance of filaments and ended with full maturity of the cob and plant lasted longer in them compared to controls, because the process of ripening was slowed down. The reduced rate of ripening was found to be connected with intensified activity and longer life of the leaves in the plants subjected to operation. There was a rule that these plants bore

leaves of more intense colour, which yellowed and aged several days later than in controls.

Along with the acceleration of growth and development of the female inflorescence, the removal of the male (terminal) inflorescence can result in the appearance of several female inflorescences on the same stem. Up to 8 female inflorescences have been observed to form in some of the plants operated at the first time (Fig. 2).

The evidence furnished by the above data is that the early removal of the male inflorescence in maize furthers both growth and development of the female inflorescences, which are axillary lateral organs. With regard to the physiological character there is a close analogy between the changes induced in maize by removing the tassels at the stage of their early development and the phenomenon observed in other plants on decapitation (i. e. removal of their vegetative summits).

The latter phenomena, according to the data supplied by experimental physiology, refer to correlative processes, which are determined by the relation in which the axial organ in plants stands to its lateral axillary organs, as regards growth and development [([10], [11]) and others]. The outward difference between the former and the latter is the stimulation of growth in the vegetative lateral shoots upon decapitation of the vegetative summits. In maize it is the removal of male inflorescence which stimulates growth and development of the female reproductive organs.

Before we finish we will refer to the data which furnish an illustration of how processes induced by the operation in question affect the grain yield in maize.

In view of the purpose later to give a detailed account concerning this question, we are reporting only part of the results obtained in comparing the productivity of experimental and control plants in the experiment of 1937. The tassels were removed by hand when pushing out from the leaf sheath. The variety Minnesota 13 extra was used for the experiment (Table 2).

Table 2

	Yield of cobs per plant		Yield of grain per plant			Absolute weight of 1000 grains, in g
	Number of cobs	Weight in air-dry conditions, in g	Number of grains	Weight in air-dry conditions, in g	In % to control	
Controls	1	105.14	436.8	89.55	100	240.7
Operated plants	1	119.18	478.6	97.81	109.2	247.7

As seen from the above data, the number of grains and their absolute weight, both are enhanced by tasseling.

The following conclusions are to be drawn from the present investigation, which had for object to clear up the physiological character of the processes induced in maize by removing its male inflorescence (tasseling).

1. The maize, bearing both male and female flowers, has following peculiarities as regards their distribution on the stem: a) the male inflorescence arranged in the form of a panicle is a terminal inflorescence and,

thus, terminates the growth of the axial organ; b) the female inflorescence united to form a cob is a lateral axillary organ.

2. Tasseling has been found to produce notable influence on the behaviour of maize plants. In the experiments reported here the operation was done at the period of early development of the tassel at two times: a) soon after formation of the terminal (male) inflorescence, and b) when the latter was pushing out of the leaf sheath.

3. Early tasseling results in: a) considerable acceleration of the appearance of female inflorescence; in the plants tested the stigmata of the pistil (filaments) were usually appearing several days later than in the controls; b) formation of several (up to 8) female inflorescences on the same plant, especially if the operation is done at the first of the times used in the experiment.

4. In plants tasseled early, the cobs develop more quickly when the grain is forming and filling, but the processes of plant ripening are somewhat slower in progress owing, as it seems, to the enhanced life activity of the leaves.

5. Early tasseling delays the destruction of green pigments in the leaves, which therefore grow yellow and old later.

6. The removal of the male inflorescence when it is pushing out of the leaf sheath has a favourable influence on grain yield in maize. Both the absolute weight of the grain and the number of grains per cob are increased.

7. With reference to their physiological character the changes induced in maize by an early tasseling are to be classified among correlative processes, i. e. such as are determined by the relation in which the axial organ and the lateral axillary ones stand to each other, as regards growth and development.

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PLANT ANATOMY

ON THE STATE OF THE CELL NUCLEI IN THE PERICARP AND THE ENDOSPERM OF WHEAT DURING THE PERIOD OF MATURATION OF THE GRAIN

By V. G. ALEXANDROV and O. G. ALEXANDROVA

(Communicated by A. A. Sapehin, Member of the Academy, 7. XII. 1938)

While studying the process of maturation of the kernels of various wheats, we became interested in changes occurring in the nuclei of the pericarp and endosperm which are most intimately associated with the very nature of maturation. Since these changes are of general interest from the point of view of cellular biology, we have decided to publish some of the results of our observations.

In wheat, like in other gramineae, the cells of the pericarp located between the exterior and interior endoderm (the so-called mesocarp) are known to obliterate and become dissolved during the ripening of the kernel. The dissolution of the cells of the mesocarp is strongly expressed in hulled wheats, e. g., in *Tr. spelta*. The mesocarp is totally dissolved, the pericarp of a mature kernel of a hulled wheat consists only of the exterior and interior epidermises (1). The dissolution of the cells of the mesocarp begins very early; at the milky maturity it is already considerably expressed, and is completed to the moment of the waxy maturity. During the earlier and the more advanced stages of maturation of the kernels of wheat highly violent biochemical processes, therefore, occur in the pericarp; they are manifested in dissolution (and their transport to the endosperm) not only of the various materials stored in the cells of the pericarp, but also of the whole body of each cell of the tissues of the mesocarp. With the dissolution of the cells of pericarp, which are very rich in contents prior to maturation of the kernel, a no less vigorous accumulation of stock-materials, chiefly of starch and protein, occurs in the cells of endosperm. The processes of dissolution, transportation and storage of food materials and plastic substances in the system pericarp-endosperm are associated with significant morphological alterations of the cell nuclei in the tissues of the two components of the kernel; they terminate in decomposition of the nuclei.

The 1st fragment of our figures represents a part of a cross-section through the mesocarp of a developing kernel of late maturing winter wheat variety «Moskovskaja 2411». The kernel is very young, formation of the endosperm only begins, only two or three peripheric layers being formed. The section passed through the basal portion of the kernel, i. e. at the place where the cells of pericarp divide and grow most intensely, thus causing the main part of the growth of the kernel itself. In many of the cells of mesocarp

meristem of the developing kernel there is no starch yet, only the nucleus and a great vacuole which fills the whole cell being visible; the vacuole evidently contains mainly sugar solution. The material was fixed with 70% alcohol. After such a fixation the nuclei of the cells not yet containing starch appear as condensed ellipsoidal bodies containing no nucleoli and consisting of a dense granular mass. All the nuclei of the pericarp as compared with those of the endosperm may be stained with difficulty. The nuclei of the endosperm, under the same conditions of fixation and staining, are stained much more rapidly and intensely.

Along with cells containing no starch, in certain places of the basal zone of the developing kernel cells of mesocarp are formed in somewhat smaller numbers in which accumulation of starch has already begun. The nuclei in such cells possess greatly different morphology, namely, they are larger, more rounded, possess a less dense content and there appear nucleoli in them. An impression is gained as if along with the formation of starch in the cell the nucleus begins to swell; other look much paler on unstained sides than do nuclei from the cells which lack starch. As starch accumulates in the cell, the number of nucleoli sometimes increases from one to two. The size of the nucleoli remains for the whole period of the existence of the cell more or less unchanged. The number of nucleoli in the nuclei of the pericarp cells of the wheat kernels never exceeds two; most commonly there is just one nucleolus per nucleus.

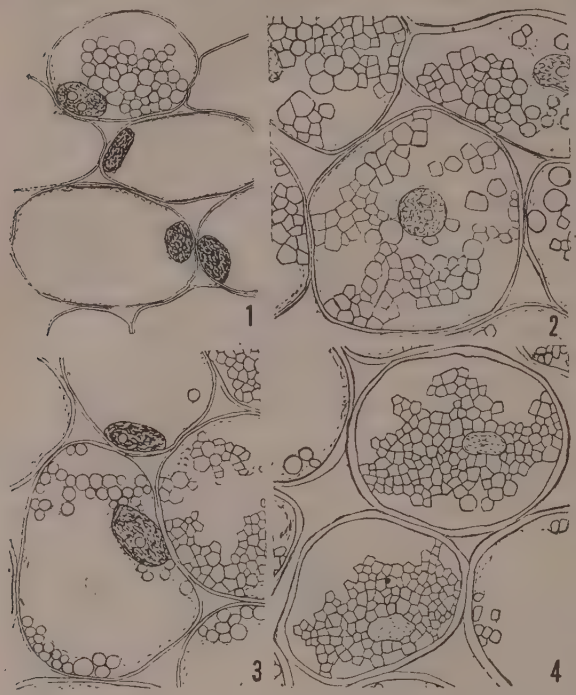
The fragment 2 represents a portion of the mesocarp tissue from the upper half of the same kernel to which fragment 1 relates. In the extreme upper regions of the kernel where the growth of the pericarp cells is considerably less than in the basal part of the kernel and cell division has ceased altogether, deposition of starch is more abundant. The cells of the parenchym of the mesocarp grow three of four times stronger than those of the same tissue from the basal part of the kernel. However, the nuclei of such cells appear to be still paler, possessing still less dense content and are still more swollen. At the same time they move to the centre of the cell and become wholly spherical.

Along with the accumulation of starch in the parenchym cells of the developing kernel of wheat, the nuclei are thus increased in size and their substance becomes less dense and less stainable. These characters show that a sort of swelling of the nuclei evidently occurs which is, however, associated with some changes of the very substance which they are composed of. Whether the changes of morphology and composition of the nuclei of the cells of the mesocarp are directly connected with the accumulation of starch in the cells, or the two processes develop independently and only parallel to each other, cannot be decided with full certainty. From the generally adopted point of view that the nucleus governs the cell activities, the parallelism between the changes in nuclear state and accumulation of starch as noted by us should be regarded as two co-ordinated phenomena of the cell's life, although the nature of this co-ordination is not yet clear.

It should be noted that starch in the pericarp cells of wheat is very small; in certain forms (e. g., endemic wheats of Afganistan, etc.) composite starch grains are rather common. The starch of the parenchym of the mesocarp is morphologically similar to the so-called chondriosomal starch of the endosperm cells (compare fragment 2 and especially 4 and 6).

Fragment 3 represents a portion of a cross-section through the mesocarp of the middle part of a developing kernel of the variety «Severnaja skorospelka» (*Ferrugineum sibiricum*). The kernel is very young yet, the formation of endosperm has only just begun. The state of the kernel is almost the same as that recorded for the late maturing variety «Moskovskaja 2411».

Formation of starch takes place in all cells of the mesocarp in the zone investigated and nucleoli become visible in the nuclei. Still more starch is formed in the upper part of the kernel (fragment 4). Strong alterations in the state of nuclei take place in the latter instance: they strongly decreased in size, their nucleoli disappear, the nuclei become deformed, lose spherical shape and undoubtedly die. An impression is gained as if the starch grains accumulated compressed the nuclei which are surrounded by them. As a matter of fact it is not true (2). The deformation of nuclei begins much earlier, than the maximum accumulation of starch in the cell is attained.



The deformation and decrease in size of the cell nuclei of the mesocarp, noted by us as taking place along with accumulation of starch in the cells, still more convincingly demonstrates the existence of a close connexion between the changes in the nucleus and the formation of starch. Dying of the nuclei in the cells of the pericarp of a maturing kernel may be biologically considered as being of advantage. Along with the dying of the nucleus the osmotic properties of the protoplasm are changed; transportation to the endosperm of such osmotically active substances, as sugar formed as a result of hydrolysis of the starch accumulated in the cells of the mesocarp, is therefore facilitated.

Our comparative studies of the early and late maturing forms of wheat have shown that nuclear alterations in the cells of the pericarp ending in their deformation and death are completed in the early maturing varieties in a shorter time and are stronger expressed than in the late maturing forms. It is a general characteristic of the early maturing varieties that processes

leading to obliteration and dissolution of the anatomical elements of the pericarp at the time of maturation of the kernel are completed in them with greater speed than in the late maturing varieties.

Fragment 5 represents a portion of the endosperm from the lower half of a kernel of the «Severnaja skorospelka». Since the material in question was collected 8 days after that which served to demonstrate the state of the cells of the mesocarp (fragments 3 and 4), the development of the endosperm here is in a considerably more advanced stage. Fragment 5 shows two cells from the deep layers of the endospermic tissue.

The nuclei of the cells of the endosperm attain considerably larger size as compared with cells of the mesocarp. Nucleoli from 2 to 7 in number appear in the endosperm nuclei very early, as soon as the nuclear division is over. The formation of the starch occurs in these cells with the same speed, especially in the deeper layers of the endosperm. We never succeeded in seeing cells of the central portion of the endosperms which contained no starch. In such cells formation of starch begins prior to the completion of the cell-formation. Growth of the starch grains proceeds also with an extreme speed. This is the plastic starch which on the average attains a large size.

Four days later one may observe in the endosperm of «Severnaja skorospelka» further alterations of the cell nuclei (fragment 6, material collected 27.VII.1938; fragment 5, material collected 24.VII). The endosperm cells have grown strongly; we have represented therefore only portions of two cells with their nuclei. Signs of deformation and dying of the nuclei are quite clear; nucleoli disappeared, nuclei have lost their spherical shape, their contours are irregular, the volume has strongly decreased. Later still the nuclei are completely decomposed. Along with the dying and decomposition of the nuclei takes place progressive accumulation of the chondriosomal starch, which toward the end of maturation fills up all spaces between the grains of the plastid starch.

Observations on the state of the cell nuclei in the mesocarp and endosperm at various moments of development of the kernels of wheat thus reveal the existence of a very close connexion between the changes occurring in the nucleus and the formation of starch in the cells. Both in the mesocarp and in the endosperm, especially in the deeper layers of the latter, the nuclei first strongly increase in size and, evidently, swell; then during the later phases of the life of the cells of these tissues they are deformed, strongly shrunk, dye and, finally, decompose. Formation and accumulation of starch continues also through the process of deformation, dying and decomposition of the nucleus, but the starch formed at this period is very small.

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ANIMAL MORPHOLOGY

NASAL CAVITY AND ITS APERTURES IN *HOLOCENTRUS*

By D. K. TRETIAKOV, Member of the Academy of the Ukrainian SSR

Among the *Acanthopterygii* fishes existing at the present time, the *Beryciformes* are considered to be the most ancient, and among them—the family of *Berycidae*. The nasal apertures are very singular in the genus *Holocentrus*, whose separate species live in tropical seas, sometimes at a considerable depth among coral reefs. Their nasal apertures are extremely rapproached, but the anterior of them has the appearance of a narrow pore that is hardly seen, and the posterior one is considerably larger, has an oval form and its diameter is almost equal to half a diameter of the pupil. It gives the impression that the nasal cavity is widely open like in the garfish.

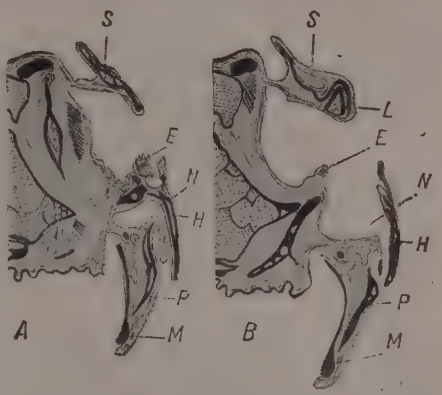
Having at my disposal specimens of *Holocentrus ascensionis* Osbek and *H. hastatus Valenciennes* (1), I paid attention to the indicated disproportionality in the dimensions of the nasal apertures. It is clearly seen in dried specimens. The larger posterior aperture increases by desiccation still more and gives the possibility to examine the nasal cavity itself. Even by such an examination, however, it is possible to persuade oneself that not the whole of it is placed opposite to the nasal apertures, but that it develops into supplementary sacs. On the mesial wall of the nasal cavity, opposite the large nasal aperture, there is seen a high fold swerving a little from the horizontal direction. It extends from the posterior wall of the cavity till to the rosette of olfactory fold that is lying with its anterior part opposite the anterior nasal aperture. This fold divides the interior mesial surface of the nasal cavity into two recesses, the upper and the lower one. The upper recess forms a projection proceeding over the olfactory rosette in the rostral direction, the lower recess proceeding to the ventral side has the appearance of a fissure, and has a similar projection.

For studying separate parts of the nasal cavity, I used a specimen of *H. hastatus* 8 cm long, i. e. in size close to Fowler's specimen that served as material for pertaining to a species characteristic given by this author. According to a general disposition of the nasal apertures, the given species differs from *H. ascensionis*, that is of much larger size, in the position of the posterior aperture which is near the ridge of the orbit. This is to be seen also in the figure in Steindachner's work (2), but the relative dimensions of both nasal apertures are wrongly rendered in this figure. In reality they are the same as in *H. ascensionis*, therefore the nasal cavity in *H. hastatus* proves to be widely opened on the cuts too (figure). In figure A, representing a similar frontal cut that has passed through the posterior part of the olfactory rosette *E*, above the recess there is to be seen the upper recess of the mesial wall. The depression in the recess partly embraces the

mesial side of the rosette too, so that the upper part of the latter projects freely into the nasal cavity, and remains fastened to the anterior end that limits the upper recess of the fold with its lower part. Under the mucous membrane of the mesial wall there is a thick layer of an extremely friable tissue that surrounds the side plate of the posterior sliding process of the praemaxillary bone. The horizontal upper plate of this very process rests upon the upper margin of the praemaxillary bone that is surrounded by a compact periosteum; with its mesial margin the plate rests on the mesethmoid. The capacity of the praemaxillary bone to protrude considerably is a common peculiarity of the *Berycidae*.

The lower part of the olfactory rosette being fastened to the fold of the mesial wall rests upon the double tendinous band, very compact in its upper part and friable in its lower one. Both the parts of the band lie on the upper end of the lateral process of the palate bones.

The lower recess has the form of a small depression under the olfactory rosette. From the outer side, the skinny lower ridge of the posterior nasal aperture borders the depression. The ridge runs downward and has the appearance of a skin fold including in itself the praeorbital (lacrymal) bone with a branched seismosensory infraorbital canal *(H)* passing through it. Lower than the thin bottom of the lower recess there is seen a space *(N)*, and an upper maxillary sac connects openly with the surrounding medium by a narrow fissure. This fissure, having in the cut a canal-like form, passes between the praeorbital bone and the fold of skin that runs down from the upper margin of the maxillary bone. The uppermaxillary sac, as the following cuts show, is an excrescence of the nasal cavity. The nasal bone, with the supraorbital seismosensory canal passing through it, lies in the upper wall of the cavity *(S)*. With its lateral ridge the bone reaches the free margin of the posterior nasal aperture. The fold of skin that includes the mesial part of the bone is separated from the middle ripple of the head; by a deep fissure the ripple corresponds to the sliding process of the praemaxillary bones. The mesethmoid with its cartilage is in the middle region of the cut *A*; beneath the mesethmoid is the high, wide part of the vomer; besides the bone it includes also the cartilage and large marrow cavities. A narrow parabasal bone is to be seen under the vomer and aside of it there are tendinous bands that fasten the anterior end of the palate bone, i. e. its horizontal plate, to the lateral projection of the vomer.



Two frontal cuts through the nasal cavity in *Holocentrus hastatus: A*, through the olfactory rosette *E*; *B*, directly beyond the rosette. Increased 3. 5 times. The explanations of the designations are in the text.

The lower recess fuses with the supramaxillary sac directly behind the olfactory rosette, and in consequence of this it acquires dimensions not smaller than those of the upper recess. The tendinous band passes in the fold *E* (Fig. *B*) that delimits them. The connexion of the supramaxillary bone with the exterior surroundings by means of the fissure in the same way changes into junction of the whole lower recess; the fissure remains limited by the skin folds of the praeorbital and praemaxillary bones (*P*).

The praeorbital bone in *Holocentrus* has a peculiar aspect. On the anterior and posterior angles of its lower margin it has two large spines, and between them there are 5 small ones of unequal dimensions. Under this jagged bony margin, the above-mentioned fissure opens along its full length and here unites the olfactory organ with the outer surroundings. The fold of skin, hanging down from the upper margin of the supramaxillary bone and limiting the fissure from the mesial side, serves evidently as a valve and prevents the water from penetrating into the nasal cavity from the side of the lower margin of the fissure. The praeorbital fissure can only let out the water that it takes in upon swift movements of the fish with the posterior nasal aperture and with the whole open part of the nasal cavity. Owing to these conditions, the anterior aperture loses its importance as an introductory one and becomes almost rudimentary. Thus, the nasal cavity in *Holocentrus* has three nasal apertures. In Fig. *B* the sliding processes of the praemaxillary bones remain over the mesethmoid, as well as the trench that divides the skin ripple that covers them from the fold with the mesial margin of the nasal bone. A wide lumen of the supraorbital seismosensory canal *S* is to be seen in the nasal bone. The nasal bone has here the appearance of a thin rugose plate. The upper corner of the lateral ethmoid bone (ethmoidale laterale) is under the curved lateral part of the plate. The vomer with the parabasal bone is under the mesethmoid. The lateral plate of the sliding process of the praemaxillary bone has disappeared here, at its place is seen only a part of the tendinous band that unites the posterior end of the lateral plate with the upper one. The lateral process of the palate bone, the anterior end of which is on the cut *A* under the olfactory rosette *E*, is sidelong from the vomer in the lower part of the cut. In the maxillary complex there is seen a fibrous plate that forms the bottom of the lower recess of the nasal cavity; it has a ripple on its lower surface. The tendinous band passes in the ripple. The outer margin of the fibrous plate forms the fold-valve of the praeorbital fissure comprising the tendinous band, and changes into the skin fold that surrounds the maxillary bone *M*, and is enveloped on its lower margin by the praemaxillary bone *P*.

The upper mesial margin of the latter projects to the mesial side, it detaches itself from the maxillary bone together with the fold of skin that covers it. The outer wall of the lower recess of the nasal cavity is formed by a fold that covers the praeorbital bone with its infraorbital seismosensory canal *H*; the upper bone margin has a fibrous border that rises to the level of the horizontal fold *E*. Still more backwards, the lower recess rapidly narrows, but does not lose the praeorbital fissure, and then terminates together with the upper recess in the gradually narrowing infraorbital sac; it accompanies the maxillary bone till the posterior spine of the praeorbital bone, viz. almost till the middle of the infraorbital margin. The fold-valve with its tendinous band remains on the mesial wall of the infraorbital sac. The nasal cavity sends off two sacs in the rostral direction; one of them, the lower or supramaxillary one, is seen in Fig. *A*. Under the anterior end of the olfactory rosette it is isolated from its outer surrounding, and its praeorbital fissure disappears because its fold-valve coalesces with the fold that comprises the praeorbital bone. The anterior end of the lateral process of the palate bone penetrates to a certain distance into the upper wall of the supramaxillary sac. Accompanying the palate bone, the supramaxillary canal reaches the place where the mesial process of the maxillary bone curves to the side of the mesethmoid and the vomer, and finally joins the latter. At this place the vomer takes the shape of a narrow sagittal plate.

The upper sac that starts from the upper recess penetrates further onward, but does not reach the mesial joint process of the praeorbital bone and termi-

nates implicitly. In the mesial wall of the upper rostral sac a tendinous band runs onward in a longitudinal rising direction; with its friably disposed bunches (beams) it composes a continuation of the friable band that lies under the olfactory rosette.

Another thick band, upon which the rosette rests, passes onward in the lateral wall of the same sac, and there it takes a rising direction and terminates together with the anterior end of the sac. Both the bands drawing together under the olfactory rosette reach the lateral process of the palate bone and get fastened to it in the posterior part of the nasal cavity.

It is yet necessary to pay attention to the peculiarity of the relief of the upper wall of the mouth cavity that is above the mouth valve. Corresponding to the narrow saggital front plate of the vomer, the mucous membrane forms a high fold comprising the lower margin of the vomer. Two deep fissures run on both sides of the fold from the two lateral ones; in their turn they are separated by a deep fissure from the maxillary brim with the lateral brim of the mouth valve that is fastened to it. The lateral folds terminate near the posterior brim of the valve and the middle fold widens and closes the rounded ends of the lateral folds; it changes into a platform that carries the teeth of the vomer.

The development of the deep fissures between the high folds in the indicated place is explained by their capacity to considerable expansions, inevitable in the case of mobility of the maxillary bones owing to their capacity of vigorous protruding. It is evident that in the case of such energetic mobility of the maxillary bones, the volume of the additional sacs of the nasal cavity that accompany them gets modified.

Therefore it has to be acknowledged that in the *Berycidae*, besides the passive penetration of water through the posterior nasal apertures, there is also an active suction of water by means of increasing the volume of additional sacs. The anterior rudimentary nasal aperture may take part in this suction too. The compression of the sac walls by the maxillary bones serves for active expulsion of water out of the nasal aperture; this is chiefly effected through the praeorbital fissure.

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ANIMAL MORPHOLOGY

OLFACTORY ORGAN IN *SARDA SARDA* C. V.

By D. K. TRETIAKOV, Member of the Academy of the Ukrainian SSR

The insufficiently ascertained peculiarity of the olfactory organ in bony fishes lies in the development of its supplementary sacs. The *Pleuronectidae* and *Labridae* may serve as example. Kyle and Ehrenbaum (1) consider that such sacs secrete slime, but they do not indicate to what purpose it is secreted.

They explain the development of supplementary sacs by a simple divergence of the cranium bones. Having found in scumber (mackerel) (2) the same peculiarity in the structure of the olfactory cavity, I considered it connected with correlatives between the cavities of the orbit and the olfactory organ. Reaching the anterior fibrous wall of the orbit, the nasal cavity gives to this wall the possibility to yield to the pressure of the contents of the orbit, when it is subjected to compression in consequence of vigorous contraction of optic muscles. Having an additional dioptric apparatus in the form of transparent lids and their not less transparent cushions, the eye uses this apparatus in augmenting the dimensions of its transferences in the horizontal plane.

In series of fishes with transparent lids that I have afterwards studied, such as *Mugil cephalus*, *Trachurus trachurus*, *Clupei* (1934—36—38), I have found also very widened nasal cavities complicated by additional projections. But at the same time one could suppose just in *M. cephalus* another possible reason for additional sacs. They undoubtedly disclose definite topographical relations with the mobile bones of the jaws, reach their joints and can evidently change their own size at the motions of bones. I am inclined to attribute to the olfactory organ of such fishes the capacity of active suction and of expulsion of water. The olfactory organ in *Sarda sarda* C. V. may serve as a convincing proof. The system of additional sacs is more complicated in it than in *M. cephalus*. They are all bound with the central section of the olfactory organ, in which there is a rosette of olfactory folds opposite to the anterior nasal aperture (*Z*, fig. *F*). The interior wall of the section that carries the rosette is limited by an annular cylinder with a sharp rib of changing height. The cavity of the central section projects above the rosette as an additional sac. Rounding it, the sac passes to its mesial side and swerves forward continuing into the supplementary rostral sac. In its transversal cut it has an oval shape (*R*, fig. *D*) and intersects with the anterior section of the upper jaw-bone; the section is lying under the sac and directs itself to the joint with the mesethmoid (*R*, fig. *C*). The rostral sac in front of the upper jaw-bone continues onward adjoining the small trench between the vomer and the mesethmoidal cartilage and

gets a rhomboid shape on the cross-section (*R*, fig. *C* and *B*). Reaching the anterior section of the praemaxillary bone, the rostral sac becomes trilateral and the sacs of the right and left sides fuse their anterior sections into the common unpaired rostral cavity (*R*, fig. *A*).

On its upper side the mesethmoidal cartilage protrudes half into the cavity; the cartilage is lying under the symphisis of the praemaxillary bones. The latter adjoin the side walls of the rostral cavity, and its bottom is an extensible plate composed of fibrous membranes of the mouth and rostral cavities. The pressure of food or water that fills the mouth must draw the fibrous bottom plate into the rostral cavity and lessen its capacity. The praemaxillary and maxillary bones that are in close proximity to the rostral sac influence upon it in the same manner. The rostral cavity

The olfactory organ in *Sarda sarda* on successive frontal cuts: *A*, region of the anterior end of praemaxillary bones; *B*, region of the anterior end of the maxillary bone; *C*, region of its posterior end; *D*, region of the anterior end of the vomer; *E*, the anterior nasal aperture; *F*, posterior part of the olfactory rosette; *K*, middle-sac; *L*, supero-ocular seismosensory canal; *M*, maxillary sac; *P*, rostral sac; *R*, rostral cavity; *Z*, central section of the nasal cavity with the rosette of olfactory folds.

terminates under the praemaxillary bone. If, beginning from the unpaired cavity, one is to watch the rostral sac backwards, then, not far from the place where it joins the central section of the olfactory organ, a thin partition may be found dividing the canal into an upper and a lower section (*H*, fig. *D*). The lower section, divided from the rostral one by the above-mentioned partition, extends backwards as an independent middle-sac. The middle-sac, as well as the rostral one, goes over to the mesial side of the anterior part of the olfactory rosette, but in its further course it changes into a narrow canaliculus flattened out on the sides (*K*, fig. *E* and *F*). It terminates under the posterior margin of the rosette. The rostral and the middle-sacs, passing mesially from the basis of the rosette, cause a certain instability of the basis of its anterior part, a possibility of its vacillation. Beyond and below the rosette the central section is in communication with the posterior sac. It consists of a narrow upper section and of a wider lower one. Behind the rosette the upper section is isolated from the lower section by a transverse horizontal partition, proceeds gradually

narrowing up to the posterior nasal aperture and terminates behind this aperture. Its thin, fibrous wall develops into an anterior lid that is likewise composed of a thin fibrous tissue.

The lower section reaches the mucous membrane of the mouth cavity (*M*, fig. *F*) accompanying backwards the praemaxillary and maxillary bones. It deserves to be termed «maxillary sac». Reaching the mucous membrane of the mouth cavity, the maxillary sac may undergo a decrease in volume in its posterior part; it occurs for the same reasons in the rostral sac too. Backwards the maxillary sac reaches not only the anterior wall of the orbit, but passes also under the orbit, till the middle of its lower margin, changing into a narrow cylindrical canal tightly closed at its posterior end, and here it accompanies the upper maxillary and praemaxillary bones. But the maxillary sac continues also onward from the central section of the olfactory cavity. Linked with the sac under the posterior part of the rosette, it is isolated by an oblique partition (fig. *E*) and starts onward touching the lower wall of the middle-sac with its upper wall. But further onward the maxillary sac gets lower and lower, keeping, however, connexion with the wall of the mouth cavity, and finally passes under the anterior section of the maxillary bone bent to the mesial side, on the transverse slit it takes a triangular shape (*M*, fig. *C*). Here under the anterior margin of the above-mentioned bone, the maxillary sac terminates implicitly. It does not reach the level of the anterior end of the rostral cavity. I consider to be the most important characteristic features of the supplementary sacs of the olfactory organ in *Sarda sarda* their immediate proximity to the wall of the mouth cavity that forms the bottom of the rostral cavity and the bottom of the maxillary sac all along its further extent. Besides this, there is a plain topographical correlation between the supplementary sacs and the mobile bones of the upper jaw. Both rostral and maxillary sacs are provided with additional narrow canals.

In 1930 I had already given a general description of the olfactory organ of the *Scumber*; this description marks the points of likeness between the olfactory organ in *Scumber* and that in *Sarda sarda*. But such likeness is yet fuller, if one pays attention to the more detailed features of the structure of the olfactory organ in *Scumber*. In its olfactory organ the scumber has a rostral sac emerging from the central section over the olfactory rosette, as in *Sarda sarda*, but it does not pass to its mesial side. Starting onward, the rostral sac is adjacent to the lateral trench of the mesethmoidal bone like the canal with the oval cross-section. At the anterior part of the maxillary bone bent in mesial direction the rostral sac expands all over the height of the head and reaches the mucous membrane of the mouth cavity. The membrane forms the bottom of the sac, and on the level of the bottom a narrow fissure sets off from the sac and penetrates between the praemaxillary and maxillary bones. The upper part of the sac, that was lying at the height of the mesethmoid, further on disappears and the lower one starts onward losing the fissure-like projection and taking the form of a gradually narrowing cylindrical canal.

Under the upper jaw-bone, the right and the left rostral canals lie in close mutual proximity and are divided from one another only by a very thin sagittal partition. But they do not fuse into the unpaired chamber, as was the case in *Sarda sarda*, and each of them terminates under the mesethmoidal cartilage and the anterior sections of the praemaxillary bones.

The *Scumber* has nothing the like of a middle-sac or its canal. Nevertheless the rostral canal in *Scumber* in its anterior part has also a fibrous wall in the mouth cavity to serve as bottom. The posterior part of the olfactory organ in *Scumber* maintains its proximity with the mouth cavity to a still

greater degree. Behind the olfactory rosette it divides into an upper and a lower part, as in *Sarda sarda*. The upper part is isolated from the lower one and reaches the posterior nasal aperture. Its outer wall has the character of a transparent cushion of the anterior lid; the young *Scumber* has this cushion jelly-like, the older one has it fibrous. In front of the partition that isolates the upper part from the lower one, the olfactory cavity comes down under the olfactory rosette as far as the mucous membrane of the mouth cavity. Under the isolating partition, the lower part of the olfactory cavity acquires the character of *Sarda sarda's* maxillary sac. It sends off a narrow fissure like projection—the intermaxillary sac, like the one in *Sarda sarda*, into the interspace between the maxillary and praemaxillary bones. Losing this projection and gradually narrowing, the maxillary sac terminates under the middle of the lower orbit of the margin. The mucous membrane of the mouth cavity serves as bottom to the maxillary sac. Attaching to the maxillary sac also its part that connects openly with the upper and central sections of the nasal cavity and is lying under the rosette, it must be said that the maxillary sac progresses also onward from the rosette until it joins the rostral sac. This junction takes place in front of the anterior section of the maxillary bone. In *Sarda sarda* there is no such junction of the maxillary and the rostral canals. But the proximity of both the sacs to the mucous membrane of the mouth cavity and to the mobile maxillary bones belongs to common symptoms of the olfactory organ both in *Scumber* and *Sarda*. The latter, however, has preserved more primitive symptoms. They serve as an argument against the mechanistical statement of Kyle and Ehrenbaum concerning the development of the sacs by way of a simple separation of bones that are lying under them. Owing to the position of the supplementary sacs with regard to the mobile bones and the mouth cavity, their own cavities became able to compress and extend; the supplementary sacs have thus developed in full functional dependence on the development of the capacity to actively suck and expulse water. They play, however, no essential part in secreting mucous, and there are no grounds to term them slimy.

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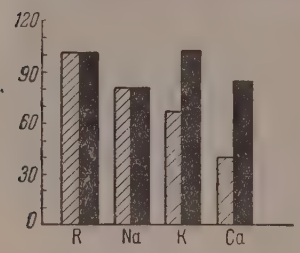
EXPERIMENTAL MORPHOLOGY

EFFECT OF EXCESS OF CHLORIDES UPON CARBOHYDRATE METABOLISM IN A TISSUE GROWN IN VITRO

By A. RUMJANTZEW and L. BEREZKINA

(Communicated by I. I. Schmalhausen, Member of the Academy, 3. XI. 1938)

It has been shown in previous papers by one of us ([1],[2]) that when NaCl, KCl or $CaCl_2$ are present in excess in the culture medium, characteristic alterations take place in the protoplasm of the cells; these alterations consist in hydratation and swelling of the protoplasm followed by the droplet separation of the liquid phase in the case of Na and K excess, and by condensation with partial coagulation when Ca is in excess.



Growth and metabolism in cultures in the presence of an excess of salts as compared with the values in the control taken for 100%. Shaded columns — growth, solid black ones—metabolism.

While studying the changes of cellular structure and the process of accumulaton of vital dyes, we became convinced that the cations penetrated into the protoplasm. The changes of cellular structures which were observed could not be regarded as degenerative, since they used to disappear as soon as the experimental cultures were transferred to an ordinary medium.

While analyzing the effect of cations upon growth and alterations of cellular structures, we became aware of the fact that gross characters due to strong disturbances of the protoplasm were applied by us to establish the effect of the salts under test. More sensitive tests had to be applied in order to make sure that the effect of cations sets in in the protoplasm by far earlier than alterations, that can be perceived under the microscope, appear.

The determination of the amount of sugar consumed by the growing tissue should be considered as such a test. This method has been worked out by Krontovsky ([3]) for cultures; it enabled the above author more than once to draw correct conclusions while testing the effect of various factors. Jatzimirskaja-Krontovskaja ([4]) has also applied this method to the study of the effect of Na, K and Ca cations; no detailed statements have unfortunately been published. It appeared, therefore, of interest to examine on a large number of cultures the action of chlorides, NaCl, KCl, $CaCl_2$, by introducing them into the medium in a moderate excess, and thus creating for the tissue living conditions that approached the physiological ones still more, than it was the case in our previous experiments.

Material and Method. Bits of the heart of an eight days old chicken embryo were placed for ½ hour into isotonic solutions of the

salts selected for the experiments. They were then transferred on mica into the medium under investigation.

In the first series of experiments the medium consisted of 2 parts of plasm plus 2 parts of the solution tested. In the second series it consisted of 2 parts of plasm plus 2 parts of the solution tested plus 1 part of 1% solution of glucose (control: plasm plus an equal part of the Ringer-solution).

In order to produce a more rapid coagulation, a small droplet of the embryo-extract was added to the medium by means of a capillary pipette. The growth was determined planimetrically after 48 hours. Evaluation of sugar content was made by the method of Haggedorm-Jenssen. The sugar content in the drops of medium containing no bits of tissue, as determined after 48 hours, was taken for the initial amount of sugar. Altogether 233 cultures were subjected to investigation.

Results of the Experiments. It should be noted in the first place that the ratio of sugar consumption always varies for different cultures within the same experiment. The cultures consume normally from 40 to 70% of sugar after 48 hours; about the same amplitude was found in cultures grown under addition of salts. This is, of course, a great disadvantage of the method adopted; however, by taking mean values from the many determinations made by us, we seem nevertheless to obtain rather reliable figures.

The table given below presents the results of the second series, which were entirely similar to those of the first one.

Media	Number of cultures	Mean initial size of the bit in cm^2	Mean size of the zone of growth after 48 h. in cm^2	Mean weight of test portion during sugar determ. in mg	% sugar consumption	Compared to control	
						Growth in %	Sugar consumption in %
Ringer	41	2.2	15.3	186	51	—	—
NaCl	19	2.1	12.4	205	41	—20*	—20
KCl	38	2.7	10.2	195	52	—33	+ 1.9
$CaCl_2$	38	2.0	6.6	169	43	—60	—17

The following conclusions can be drawn from the table above.

1. The conclusions arrived at in the previous investigations, namely, that $CaCl_2$ possesses the greatest inhibiting effect upon growth, NaCl, on the contrary, the smallest, while KCl occupies an intermediate position, are once more verified on cultures with a smaller amount of the salt tested.

2. There is no simple relation between the growth inhibiting action of the salts and their influence upon the metabolism; this may be seen from the accompanying graph.

If we evaluate sugar consumption per unit of increment of area, cultures grown in control media prove to show the lowest figures; in all the other cases sugar consumption increases. The conclusion to be made is that K and Ca are stimulating sugar consumption; if the evaluation is made using the above procedure, Ca proves to assume the first place.

Such a conclusion would, however, be erroneous, since no correct solution of the problem can be attained without taking into account density of the zone of growth. We observe minimum density in KCl and maximum density in $CaCl_2$, while in NaCl it approaches to the normal one.

* Sign—before the figures of the two last columns signifies the reduction, +the increase as compared with control.

This circumstance being taken into consideration, we can but admit that KCl is stimulating sugar consumption by growing tissue in a more intensive way than other salts.

3. A sharp discrepancy with regard to the action of salts upon growth becomes apparent, when our data are confronted with those of Krontovskaja; this is especially true for KCl which, according to the observations of this author, should cause a maximum growth inhibition; at the same time it may be noted that the conclusion she had arrived at as to the maximum stimulation of sugar consumption in KCl proved to be correct.

4. Microscopic investigation of the cytoplasm of the growing cells made by us after 48 hours revealed a slight vacuolization in KCl and some condensation in $CaCl_2$; however, no striking alterations like those described by us in our previous papers could be observed in the present experiments. Now such a slight vacuolization and a certain stretching of cells, as well as a reduced deposition of stains in the cytoplasm, was pointing to that the trend of the alterations which were setting in was a typical one. If this is the case, we are free to conclude that when hydratation or dehydration of the protoplasm are caused by NaCl and KCl, or $CaCl_2$, respectively, the protoplasm needs for a certain time more energy than under normal conditions, which immediately tells upon sugar consumption from the surrounding medium.

5. It is known from the works by Lipmann ([5]) and Laser ([6]) that a tissue growing in vitro is consuming sugar not only for respiration, but for fermentation too. Observations show that the two processes may be stimulated both by K and Ca. Thus, Ashford and Dixon ([7]) (brain), Rosenthal ([8]) (liver), Lasnitzki ([9]) (yeast) and others have established an increase in fermentation under the influence of KCl. As to $CaCl_2$, the concentration seems to account either for increase (Lasnitzki) or decrease (Rosenthal) in fermentation.

From the study of respiration all the authors ([10]—[12],[7]) arrived at a conclusion that both K and Ca are stimulating respiration.

We wish to note that the experiments referred to above were conducted by the method of Warburg. Our observations are not at variance with the results of these experiments, for when sugar consumption increases, the processes of its aerobic and anaerobic splitting are necessarily enhanced. Inasmuch as increase in consumption is observed when any of the three salts is present in excess, we feel justified to conclude that K and Ca (possibly, Na too), being present in definite concentrations, enhance the energy processes occurring within the protoplasm. Lasnitzki brings this in connexion with swelling. However, we cannot fully share his opinion, in so far as stimulation of sugar consumption has been proved by us for Ca also, i. e. for the very salt which causes dehydration of the protoplasm. Some other mechanisms seem thus to be responsible for this phenomenon.

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